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Public Health Service

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi per square meter (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi per square mile
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs per gram

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 8, Number 8, August 1967

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • National Center for Radiological Health

Reports

Strontium-90 in Human Bones, 1964–1965

R. M. Hallisey and *M. A. Wall* [1]

Results obtained from analysis of strontium–90 in human bone specimens from 303 individuals who died in 1964, and 293 individuals who died in 1965 have been studied. The bone specimens were collected at autopsies in selected metropolitan cities throughout the United States. A summary table of all the data for deaths occurring in 1964 and 1965 is presented. In most of the five age groups in 1965, average values are slightly lower than the 1964 values. Regional variations in the strontium–90 to calcium ratio are shown with the highest average for each year in the Delta region. The data were related to human bone concentrations that were derived from the Federal Radiation Council's Radiation Protection Guides and intake ranges, and it was shown that in both years the average bone concentrations correspond to Range I of these intake guides.

In the latter part of 1961, the National Center for Radiological Health (then the Division of Radiological Health) of the Public Health Service initiated an investigation into the levels of strontium–90 in human bones. This project was a continuation of a study by Kulp and Schulert at the Lamont Geological Laboratory which was terminated in 1961 (*1*). Previous papers have reported results on samples from deaths occurring through 1963 (*2–4*). This present paper summarizes the results of analyses of human bone specimens from 303 individuals who died in 1964, and 293 individuals who died in 1965. The analytical data on these 596 specimens have appeared in previous issues of *Radiological Health Data and Reports* (*5*).

Bone specimens from autopsies are collected by pathologists, medical examiners, and coroners in selected metropolitan cities throughout the United States (figure 1). For comparison purposes, concentrated collection efforts are maintained around five principal cities; namely, Boston, Mass.; Cincinnati, Ohio; New Orleans, La.; Seattle, Wash.; and Los Angeles, Calif. With the exception of a few samples obtained at surgical procedures, the specimens are limited to those obtained from accident victims or persons who have died of an illness not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount of bone is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. The population group of particular interest is infants and young adults up to 25 years of age. Most of the bone specimens involved in this report are vertebrae or ribs.

Analytical procedure

The bones are analyzed at the Northeastern Radiological Health Laboratory, Winchester, Mass., a field laboratory of the National Center for Radiological Health. Before analysis, the specimens are ashed in two stages, the final stage being at 800° C. in aluminum oxide crucibles. In the original procedure, a fraction containing yttrium–90, in equilibrium with its parent, strontium–90, was separated from the bone ash by extraction with 2-thenoyltrifluoroacetone (TTA). Starting with the 1964 samples, the procedure was changed so that the yttrium is purified by tributyl phosphate (TBP) extractions.

A suitable portion of bone ash (5 to 10 grams) is dissolved in 1:1 nitric acid. Stron-

[1] Mr. Hallisey is presently chief, X-ray Project and Mrs. Wall is a statistician at the Northeastern Radiological Health Laboratory, Winchester, Mass. 01890.

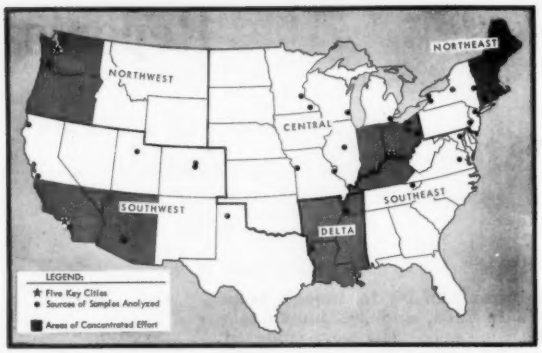

Figure 1. Regions for PHS Bone Sampling Network

tium and yttrium carriers are added. Fuming nitric acid is added to precipitate strontium and separate the strontium–90 from its daughter, yttrium–90. The yttrium–90 is purified by extraction into tributyl phosphate, and back extracted into dilute nitric acid. It is then concentrated by precipitation as the oxalate, dried, weighed to determine chemical recovery, and counted for beta radioactivity in a low-background beta-particle counter. With the application of proper decay and chemical recovery factors, the yttrium–90 activity is calculated. Because the strontium–90 and yttrium–90 are in equilibrium, the determined yttrium–90 activity is an indirect measurement of the strontium–90 concentration (*6*).

This procedure is an adaption of a previously reported procedure (*7,8*). It yields results comparable to those obtained by the TTA procedure, is shorter, and requires essentially no platinumware. The purity of the yttrium–90 is checked by decay measurements over several half-lives. A number of human bone samples were analyzed by both methods and an analysis of variance of the data showed no significant difference between the results of the two methods.

For the purpose of maintaining analytical quality control, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. In addition, "spiked" synthetic bone ash samples have been prepared and are analyzed routinely. Through the Analytical Quality Control Service of the National Center for Radiological Health, a cross-check program with the Health and Safety Laboratory of the Atomic Energy Commission is conducted monthly. Preliminary results of the first 6 months of this program show satisfactory agreement between the two laboratories.

Results

A summary of these data is presented in table 1. In each of the five age groups, the 1965 average values are generally slightly lower than the 1964 values. However, the highest single bone concentration (11.7 pCi/g of calcium) was reported for an 8-month old child in 1965 in the southwestern region of the United States. On the average, the levels in the Southwest region are consistently lower than those of any of the other five regions. The combined regional averages for 1964 and 1965 are shown in figure 2. This figure indicates definite regional variations in the strontium–90/calcium ratio in human bone among the six regions. For each year tested, the Delta region had the highest average and the Southwest region had the lowest average. This relationship is consistent with that observed for strontium–90 in the pasteurized milk and institutional diet networks as reported in previous issues of *Radiological Health Data and Reports.*

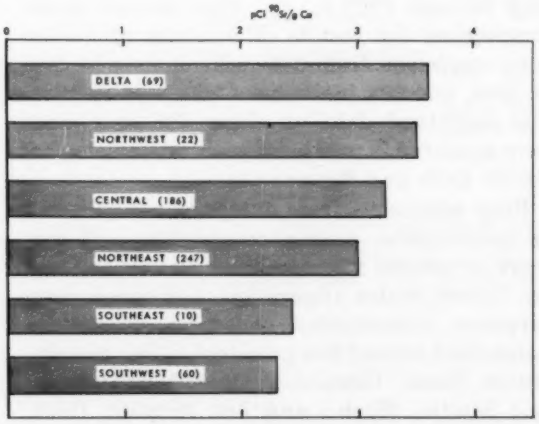

Figure 2. Combined data regional averages, 1964 and 1965

The frequency distribution for strontium–90 in human bone specimens in the years of 1964 and 1965 is shown in figure 3. The strontium–

Table 1. Strontium-90 in human bones by year of death, age and region (pCi strontium-90/g calcium)

Region	1964 deaths																				Total number
	0–4 years				5–9 years				10–14 years				15–19 years				20–24 years				
	No.	Max	Min	Mean	No.	Max	Min	Mean	No.	Max	Min	Mean	No.	Max	Min	Mean	No.	Max	Min	Mean	
Northeast	17	8.4	2.6	5.0	30	7.0	1.2	3.6	37	5.7	1.5	3.3	31	5.4	1.2	2.9	33	3.9	0.8	2.2	148
Southeast	NS	NS	NS	NS	NS	NS	NS	NS	1	NA	NA	2.3	1	NA	NA	2.7	1	NA	NA	2.1	3
Central	35	8.7	1.8	4.7	21	6.2	1.7	3.8	6	4.0	1.8	2.8	12	4.7	1.3	2.3	11	3.4	1.0	2.0	85
Delta	3	6.7	3.7	5.4	5	5.4	2.9	4.2	4	4.9	2.9	3.5	10	5.1	2.0	3.6	4	4.3	1.5	2.8	26
Northwest	1	NA	NA	3.2	2	5.2	4.3	4.7	1	NA	NA	5.6	2	6.1	2.7	4.4	4	3.9	0.6	2.3	10
Southwest	12	5.0	1.0	2.7	6	3.4	1.4	2.4	7	3.4	0.9	2.1	2	2.0	2.0	2.0	4	3.0	1.6	2.4	31
All regions	68	8.7	1.0	4.4	64	7.0	1.2	3.6	56	5.7	0.9	3.1	58	6.1	1.2	2.9	57	4.3	0.6	2.2	303
	1965 deaths																				
Northeast	16	8.9	2.4	3.9	21	5.5	2.1	3.4	17	3.8	0.9	2.7	27	3.5	1.5	2.4	20	2.8	1.3	2.1	101
Southeast	NS	NS	NS	NS	2	3.0	2.5	2.7	NS	NS	NS	NS	3	2.6	2.2	2.3	2	2.8	1.9	2.4	7
Central	32	7.8	1.4	4.2	16	5.9	1.4	2.6	17	5.2	1.5	2.6	17	3.8	1.3	2.2	19	2.6	1.0	1.8	101
Delta	16	10.2	2.8	5.2	7	6.4	2.6	3.8	9	3.5	1.1	2.7	5	2.9	1.3	1.9	6	3.0	1.0	2.1	43
Northwest	3	5.7	3.3	4.5	2	2.8	1.7	2.3	3	4.4	2.7	3.4	3	4.7	1.8	3.6	1	NA	NA	1.3	12
Southwest	14	11.7	0.7	2.6	6	3.6	1.3	1.9	2	2.3	2.3	2.3	3.	2.5	1.5	2.1	4	1.5	1.0	1.2	29
All regions	81	11.7	0.7	4.1	54	6.4	1.3	3.0	48	5.2	0.9	2.7	58	4.7	1.3	2.3	52	3.0	1.0	1.9	293

NS, no samples collected.
NA, not applicable.

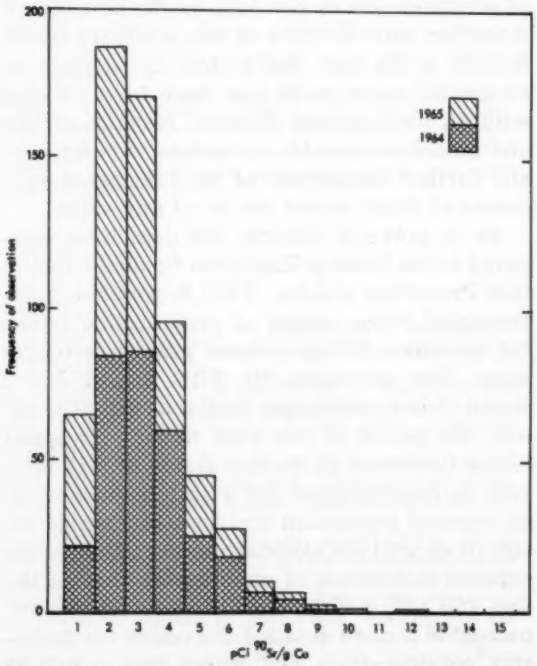

Figure 3. Frequency distribution for 1964 and 1965 deaths

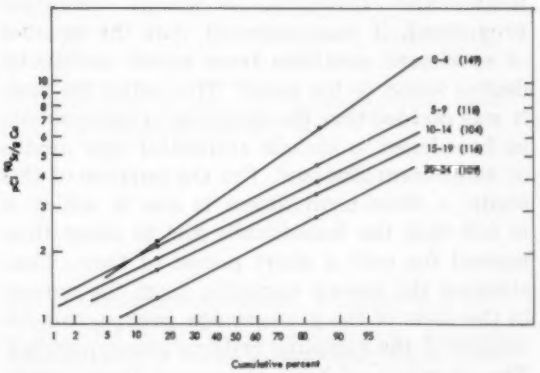

Figure 4. Strontium-90 to calcium ratios in human bone

90/calcium distribution is skewed for all 1964 and 1965 samples. Similar skewed distributions were obtained for each of the age groups for these years. As shown in previous papers (*3,4*), a logarithmic probability plot (figure 4) clearly indicates that the distribution is log normal, consistent with earlier observations of Kulp and Schulert (*1*) on whole skeleton samples obtained in New York. Similar logarithmic probability plots and frequency distributions are obtained when the data from other years are plotted.

Figure 5 is a plot of the median pCi of strontium–90/gram of calcium versus age for 1964 and 1965. Since the data are not normally distributed, it is felt that the median is the more significant value, although the mean value is useful in comparison with other data. With the exception of the 0- to 12-month group, the median values are higher for the 1964 bone specimens than for the 1965 specimens.

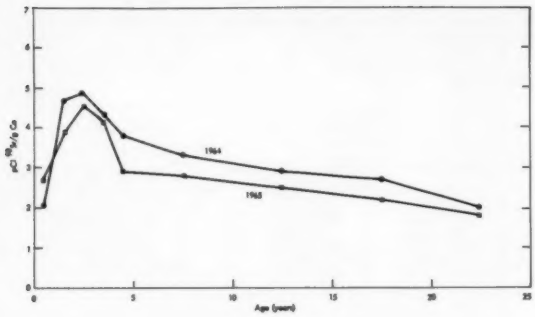

Figure 5. Median versus age

Discussion

In the original sampling protocol, it was decided that only specimens from accidental deaths would be analyzed, since these should more closely represent average values for living individuals. However, as sample collection progressed, it was apparent that the number of specimens available from purely accidental deaths would be too small. This being the case, it was decided that the sampling criteria should be broadened to include accidental type deaths or short-term illnesses. For the purpose of this study, a short-term illness is one in which it is felt that the individual's diet is other than normal for only a short period of time. Considering the known variation from the normal in the diets of the younger age groups, this extension of the sampling criteria seems justified. The shortage of bone specimens from purely accidental deaths may also be accounted for by the fact that in many areas of the country autopsies are not performed on young individuals who have died from obviously accidental causes. Taking the above facts into consideration, a large number of bone specimens from non-accidental deaths have been analyzed. For comparison purposes, the samples were placed in three arbitrary classifications according to the cause of death. The three classifications were as follows: (a) accidental deaths; (b) non-accidental deaths in which, in the normal course of the specific illness, calcium levels and kinetics are known to be not usually affected; (c) non-accidental deaths in which, in the course of the specific illness, calcium levels and kinetics may be affected.

In addition, the individuals [2] classifying the specimens were cognizant of the effect of extended disuse of bone on calcium kinetics. Autopsy specimens from persons whose illnesses inherently affected calcium levels and kinetics were eliminated. Once all specimens were classified, they were grouped by age at death and cause of death. An additional classification of specimens by region proved impracticable because of the small number of samples in some age/region/cause of death categories. An analysis of variance test was performed and no significant difference was observed in the strontium–90/calcium ratios among the age/cause of death categories.

Although it should be remembered that this classification is purely arbitrary, it still appears probable that the strontium–90/calcium ratios would not differ even though the total amount of strontium–90 in the bone might be affected. A further consideration of this arbitrary classification is the fact that a child dying from an accidental cause could also have been afflicted with an undiagnosed disease. Because of this and numerous possible variations, it is felt that any further comparison of the data based upon causes of death would not be of any value.

As in previous reports, the data were compared to the Federal Radiation Council's Radiation Protection Guides. FRC Report No. 2 (*9*) presented three ranges of radionuclide intake for guidance during normal peacetime operations. For strontium–90, FRC Report No. 2 stated that a continuous intake of 200 pCi/day over the period of one year would correspond to the Radiation Protection Guide of 0.17 rad/year to mineral bone for a suitable sample of an exposed population and that this would result in an average skeletal concentration in the exposed population of one quarter that in the diet (50 pCi/g Ca). FRC Report No. 7 (*10*) presented a more detailed discussion on dosimetry considerations and stated that 1 nCi of strontium–90 in adult bone would result in a dose of 2.7 rads/year to mineral bone. There-

[2] The bone specimens were classified on the basis of information from death certificates by Ronald Seltzer, M.D., a consultant from the Massachusetts General Hospital, and David E. P. Fitzpatrick, M.D., staff medical officer at the Northeastern Radiological Health Laboratory.

fore, the concentration corresponding to the Radiation Protection Guide of 0.17 rad/year would be 6.3 pCi/g Ca. FRC Report No. 7 also stated that the dose to mineral bone of the fetus and infant may be one-half that of the adult value because of less mineral content and less absorption of available beta-particle energy, resulting in a concentration of 126 pCi/g Ca corresponding to 0.17 rad/year. These values are summarized in table 2. The highest single value for an individual, 11.7 pCi of strontium–90 per gram of calcium, which was measured in the 0- to 4-year-age group in 1965, is within the guides corresponding to Range I. Consideration of the averages within the five age groups for both 1964 and 1965 reveal that Range I was not exceeded. Because of unavoidable deficiencies in the sampling programs, especially the lack of samples from certain age groups in certain regions, no definite interferences on population averages can be made.

A comparison of the data from Germany, England, and the United States (Public Health Service and Atomic Energy Commission) is shown in table 3 (*11–14*) for 1963, 1964 and 1965. In general, the values are not dissimilar, allowing for the differences due to sampling techniques and geographic locations.

Table 2. Strontium-90 concentrations in mineral bone corresponding to Federal Radiation Council daily intake ranges, pCi/g calcium

FRC intake range [a] (pCi/day)	Population "average"			Individuals		
	FRC #2	FRC #7		FRC #2	FRC #7	
		Adults	Infants		Adults	Infants
I (0–20)	0–5	0–6.3	0–12.6	0–15	0–19	0–38
II (20–200)	5–50	6.3–63	12.6–126	15–150	19–190	38–380
III (200–2,000)	50–500	63–630	126–1,260	150–1,500	190–1,900	380–3,800

[a] Based on a radiation protection guide of 0.17 rad/year, which corresponds to the upper value of range II.

Table 3. Average strontium-90 levels in human bone, United States and Europe

Age group	Year	PHS	AEC [a]	Germany	England
0–4	1963	4.3 (44) [b]	3.6 (72)	3.7 (30)	4.7 (165)
	1964	4.4 (67)	3.6 (64)	5.4 (36)	7.9 (130)
	1965	4.1 (81)	4.3 (43)	5.9 (19)	7.9 (84)
5–19	1963	3.2 (163)	1.8 (64)	1.4 (27)	1.6 (74)
	1964	3.2 (178)	2.7 (67)	2.8 (28)	2.2 (46)
	1965	2.7 (160)	2.9 (58) [c]	2.7 (13)	2.8 (41)

[a] Average of tri-city study (New York City, Chicago, and San Francisco)
[b] Parentheses gives number of samples making up average.
[c] Chicago samples were not collected in 1965.

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Uptake of Cesium-137 From Contaminated Soil by Selected Grass Crops

H. L. Cromroy,[1] *W. A. Goldsmith,*[1] *C. R. Phillips,*[2] and *W. P. Bonner* [1]

The cesium–137 content of milk in the Tampa, Fla. area has been consistently above the national average in recent years. The possibility that grasses grown in this area receive their contamination indirectly through contaminated soil is being investigated. Among the grasses investigated the uptake of cesium–137 appears to be greatest for pangola grass.

The cesium–137 content of milk in the Tampa, Fla. area has been consistently higher than the national average in recent years. This high concentration of cesium–137 has been reported to be related to the pangola grass feed received by dairy cows in this area (*1*). It is possible that grasses grown in this area received their contamination indirectly through contaminated soil, since direct deposition of fission products on the foliage would affect all hays equally, as indicated by Csupka *et al* (*2*).

The primary purpose of this investigation is to determine the difference in uptake of cesium–137 from contaminated soil by four hay crops (Tampa pangola, Gainesville pangola, Bahia, and Bermuda) indigenous to the State of Florida. If the uptake of cesium–137 by pangola grass is confirmed to be greater than the uptake by other grasses, the results may be useful for determining which grasses may be used as dairy feed without resulting in a high cesium–137 content in milk.

Procedure

The soil studied was obtained from a large dairy farm in the Tampa area on May 16, 1966. This soil was identified as Ona fine sand, belonging to the Scranton-Ona group which occurs on poorly drained, nearly level areas in northern and central Florida. Typical mechanical and chemical analyses of Ona fine sand are given in tables 1 and 2. The organic matter in this soil has a cation exchange capacity of less than 10 meq/100 g. The clay fraction has been identified as kaolinite (*3*). Kaolinite exhibits the properties of ion exchange and adsorption, but its interlayer spacing is not favorable for "structural adsorption." Thus, mass permanent fixation of cesium is not likely in this soil (*4–7*).

The soil samples were freed from the roots of pangola and weeds by shaking. After a thorough mixing, it was spread to a depth of about 5 inches in a 4- by 9-foot tray and subsequently divided into four plots, each 4 by 2¼ feet.

The three grasses chosen for this study represent grasses commonly used for pasture and hay in Florida. Pangola (*Digitaria decumbens*), Bermuda (*Cynodon dactylon*), and Bahia (*Paspalum notatum*), were obtained from plots under investigation by the Department of Agronomy at the University of Florida. These grasses were obtained by means of a core sampler on May 12, 1966 (2 days prior to the arrival of fallout from a recent surface burst on mainland China). All grasses were stored in the greenhouse prior to being sprigged into

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[2] Mr. Phillips is presently employed at the Northeastern Radiological Health Laboratory, NCRH, Winchester, Mass.

Table 1. Typical mechanical analysis of Ona fine sand [a]

Depth in inches	Moisture equivalent (percent) [b]	Very coarse sand (percent) [c]	Coarse sand (percent) [c]	Medium sand (percent) [c]	Fine sand (percent) [c]	Very fine sand (percent) [c]	Coarse silt (percent) [c]	Fine silt (percent) [c]	Clay (percent)
0–6	6.78	0.5	7.4	17.0	60.0	11.3	1.9	0.6	1.3
6–10	8.81	.9	7.0	15.3	59.6	11.6	3.3	.6	1.7
10–18	3.32	1.1	7.2	15.5	60.0	11.3	2.5	.7	1.7
18–42	2.15	.8	7.2	15.7	60.5	11.7	1.8	.4	1.8

[a] Reference (*8*).
[b] Percent of total weight.
[c] Percent of solids.

Table 2. Typical chemical analysis of Ona fine sand [a]

Depth in inches	Organic matter (percent)	Total nitrogen (percent)	Total phosphorous (percent)	Cation exchange capacity (meq/100g)	Exchangeable cation			
					Ca (meq/100 g)	K (meq/100 g)	Mg (meq/100 g)	Reaction pH
0–6	4.47	0.108	0.019	7.97	0.59	0.068	0.47	4.72
6–10	4.03	.089	.017	7.07	.12	.027	.08	5.22
10–18	.72	.021	.017	1.11	.06	.015	.03	5.45
18–42	.20	.009	.033	.60	.06	.006	.04	5.18

[a] Reference (*8*).

the Tampa soil on May 20, 1966. For comparison purposes, pangola grass from the Tampa area was also used.

Approximately 2 weeks later, the plots were treated with 10–10–10 commercial fertilizer at a rate equivalent to 300 pounds/acre, as recommended by the Department of Agronomy at the University of Florida. All foliage was cut to a height of 2½ inches on June 1, 1966. Optimum growing conditions were maintained by controlling the temperature between 80° to 90° F. with light watering each day except weekends. Grasses were cut to a height of 4 inches above the soil on June 28, 1966, and again on July 28, 1966, and subsequently analyzed to determine their cesium–137 concentration.

The uptake of cesium–137 by the soil was determined by means of a slurry test, similar to the procedure described by Lacy (*8*). The water for the slurry was spiked with enough cesium–137 to obtain a statistically valid total activity during a 2-minute counting period of a 2-milliliter sample. Preweighed amounts of dried soil were then added and the resulting suspensions were slurried by means of a magnetic stirring device. After 90 minutes of slurrying, the samples were filtered. Two-milliliter samples of the filtrate were then counted to determine the amount of cesium–137 which had been absorbed by the clay.

The samples of grass were counted in 1-liter Marinelli beakers. The counting system consisted of a right cylindrical sodium iodide (thallium activated) crystal with dimensions of 4 by 4 inches and a 400-channel pulse height analyzer.

The gamma-ray spectra were analyzed by a modified stripping technique in order to correct for interference from other gamma-emitting nuclides in the cesium–137 region. The daughters of radium–226 from the natural uranium decay chain present in the soil were the largest contributors of interfering radioactivity.

The grass samples were heated to 105° C. for 24 hours following counting. The concentration is reported in terms of this dry weight so that all values would be based on an equivadent moisture content.

Results

Cesium–137 uptake by Tampa soil (table 3) is much less than that reported by Straub (*9*) or Goldsmith (*10*) for other types of soil. However, the results reported in the literature were obtained on soils which contained almost 100 percent clay fraction (Tampa soils contain less than 5 percent). In addition, the soils investigated by Straub and Goldsmith contained clays which were generally montmorillonite or vermiculite which have high cation exchange capacities and adsorptive properties whereas kao-

Table 3. Average data for uptake of cesium-137 by Tampa soil

Sample	Clay dosage (mg/liter)	Influent activity (cpm/ml)	Effluent activity (cpm/ml)	Percent removal
1	503	5.08×10^3	3.65×10^3	28.3
2	2,013	4.88×10^3	3.42×10^3	29.9
3	3,019	4.87×10^3	3.33×10^3	31.5
4	4,001	5.54×10^3	3.74×10^3	32.5
5	5,016	6.02×10^3	4.09×10^3	32.0
6	7,010	6.17×10^3	4.06×10^3	34.3

linite found in Tampa soil is rather low in adsorptive capacity.

Since Tampa soil contains a small fraction of clay which has been identified as kaolinite, and no linear plot was obtained for an adsorption isotherm, it is most probable that if any uptake of cesium–137 by Tampa soil occurs, it is by an ion exchange process.

The cesium–137 concentrations in the various grasses as determined by counting on June 28 and July 28 are given in table 4 and 5, respectively. For unexplained reasons the growth of the Bermuda was retarded following transplantation. As a result, an insufficient sample was obtained on the second cutting for a statistically significant determination of its cesium–137 activity. Hence, no interpretation can be made of the data obtained from this grass.

Bahia appears to have matured more rapidly than pangola in this investigation. This was evidenced by the fact that the Bahia was in the anthesis stage of maturity while the Pangola was in the pre-early boot stage at the time of both cuttings.

Table 4. Concentration of cesium-137 in grasses on June 28

Grass	Cesium-137 radioactivity (pCi/kg dry weight)
Tampa pangola	[a] $(3.9\pm.6)\times10^3$
Gainesville pangola	$(1.2\pm.5)\times10^3$
Bahia	$(2.8\pm.6)\times10^3$
Bermuda	$(1.3\pm.6)\times10^3$

[a] Two σ counting error.

Table 5. Concentration of cesium-137 in grasses on July 28

Grass	Cesium-137 radioactivity (pCi/kg dry weight)
Tampa pangola	[a] $(4.2\pm.8)\times10^3$
Gainesville pangola	$(2.7\pm.7)\times10^3$
Bahia	$(2.8\pm.6)\times10^3$
Bermuda	[b]

[a] Two σ counting error.
[b] Below detectable limits (because of the small amount of sample available.)

The concentration of cesium–137 varied from 1,296 to 4,220 pCi/kg (dry weight). The value for Tampa pangola is in agreement with that of Porter *et al* (*1*), for hay grown in the Tampa area. Although the concentration of cesium–137 in Gainesville pangola did not equal that of the Tampa pangola, the concentration more than doubled from the first to the second cutting, suggesting an approach to a stabilization level.

Tampa pangola had been growing in its native soil for several years and presumably had reached stabilization with the cesium–137, as evidenced by the negligible difference in the concentrations present in the two cuttings. Presumably, the cesium–137 concentration in Gainesville pangola would continue to increase until the cesium–137 concentration equaled that of the Tampa pangola.

It appears that the Bahia grass reached a stabilization concentration more rapidly than Gainesville pangola. This may be attributed to the more rapid rate of maturity observed for the Bahia grass.

Gammon (*11*) reports that the minimum potassium requirement for these grasses varies from 6 to 20 mg/kg of dry forage with pangola having the highest requirement followed by Bermuda and Bahia, in that order. The concentration of cesium–137 in the pangola and Bahia grass follows the potassium requirements as determined by Gammon. On this basis, a knowledge of the relative potassium requirements of plants provides a prediction of their relative cesium–137 uptake.

Conclusions

The current research gives some evidence that part of the cesium–137 content in the soil plots from the Tampa area is in an exchangeable form. There is also an indication that the uptake of cesium–137 by pangola is the most extensive among the grasses investigated.

Three areas of further study are suggested as a result of this investigation. First, a similar study for a much longer period of time in order to permit cesium–137 uptake by all grasses to reach a stabilization level would be valuable. Second, the effect of various fertilizers on the uptake of cesium–137 should be investigated.

Finally, other soil types and hay crops should be studied to be compared with the present studies.

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SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Both Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake of the short-lived radionuclides. For these reasons, milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake from the consumption of 1 liter of milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for assessing the hazards of normal peacetime nuclear operations, assuming continuous exposure of the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk.

In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January–June 1966	March 1967

1. Pasteurized Milk Network April 1967

National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN), was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent de-

Table 1. Analytical errors associated with determinations of radionuclide concentrations in milk

Radionuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Iodine-131	Less than 100	10	100 or greater	10
Barium-140	Less than 100	10	100 or greater	10
Cesium-137	Less than 100	10	100 or greater	10
Strontium-89	Less than 50	5	50 or greater	10
Strontium-90	Less than 20	2	20 or greater	10

[a] Two standard deviations.

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentration of radionuclides in pasteurized milk for the first quarter 1967 and April 1967[a]

Sampling location		Radionuclide concentration (pCi/liter)							
		Strontium-89		Strontium-90		Iodine-131		Cesium-137	
		First quarter 1967	April 1967[b]	First quarter 1967	April 1967	First quarter 1967	April 1967	First quarter 1967	April 1967
Ala:	Montgomery	<5	< 5	12	12	10	0	15	20
Alaska:	Palmer	<5	< 5	9	6	0	0	20	25
Ariz:	Phoenix	<5	< 5	2	7	0	0	< 5	< 5
Ark:	Little Rock	<5	< 5	23	28	0	0	20	20
Calif:	Sacramento	<5	15	3	5	0	0	< 5	10
	San Francisco	<5	10	4	5	0	0	< 5	15
C.Z:	Cristobal	<5	< 5	6	5	0	0	25	35
Colo:	Denver	<5	< 5	6	5	0	0	< 5	5
Conn:	Hartford			10	9	0	0	25	20
Del:	Wilmington			11	11	0	0	20	20
D.C:	Washington	<5	< 5	10	10	0	0	15	20
Fla:	Tampa	<5	< 5	9	9	0	0	70	70
Ga:	Atlanta	<5	< 5	17	17	10	0	25	25
Hawaii:	Honolulu	<5	< 5	5	5	0	0	15	15
Idaho:	Idaho Falls	<5	< 5	7	6	0	0	10	15
Ill:	Chicago	<5	< 5	9	11	0	0	20	20
Ind:	Indianapolis	<5		10	10	0	0	20	15
Iowa:	Des Moines	<5	< 5	9	9	0	0	10	15
Kans:	Wichita	<5	< 5	9	7	0	0	5	10
Ky:	Louisville	<5	< 5	14	15	0	0	15	10
La:	New Orleans	<5	< 5	27	29	0	0	35	30
Maine:	Portland	<5		13	11	0	0	45	30
Md:	Baltimore	<5	< 5	11	12	0	0	20	25
Mass:	Boston	<5	< 5	13	12	0	0	35	30
Mich:	Detroit			10	9	0	0	20	20
	Grand Rapids	<5		11	12	0	0	25	25
Minn:	Minneapolis	<5	< 5	14	15	0	0	15	20
Miss:	Jackson	<5	< 5	21	25	10	0	20	20
Mo:	Kansas City	<5	5	10	9	0	0	5	10
	St. Louis	<5	5	11	10	0	0	10	15
Mont:	Helena	<5	< 5	7	6	0	0	10	10
Nebr:	Omaha	<5	< 5	10	7	0	0	10	20
Nev:	Las Vegas	<5	< 5	3	2	0	0	< 5	< 5
N.H:	Manchester	<5		16	13	0	0	45	50
N.J:	Trenton	<5		10	10	0	0	25	25
N. Mex:	Albuquerque	<5	< 5	5	4	0	0	< 5	< 5
N.Y:	Buffalo	<5		9	9	0	0	20	20
	New York City	<5		11	11	0	0	20	20
	Syracuse	<5		9	8	0	0	20	20
N.C:	Charlotte	<5	< 5	18	21	0	0	20	20
N. Dak:	Minot	<5	5	17	18	0	0	15	25
Ohio:	Cincinnati	<5		11	11	0	0	20	15
	Cleveland	<5		12	10	0	0	20	20
Okla:	Oklahoma City	<5	< 5	10	11	0	0	10	15
Ore:	Portland	5	10	8	11	0	0	10	25
Penn:	Philadelphia	<5		11	10	0	0	20	15
	Pittsburgh			13	14	0	0	25	25
P.R:	San Juan	<5	< 5	5	4	0	0	15	15
R.I:	Providence	<5		11	11	0	0	30	25
S.C:	Charleston	<5	< 5	18	18	20	0	30	30
S. Dak:	Rapid City	<5	5	11	11	0	0	15	20
Tenn:	Chattanooga	<5	< 5	16	18	0	0	20	20
	Memphis	<5	< 5	13	15	0	0	10	10
Tex:	Austin	<5	< 5	4	4	20	0	10	5
	Dallas	<5	< 5	9	11	10	0	10	15
Utah:	Salt Lake City	<5	< 5	7	6	0	0	10	15
Vt:	Burlington	<5		11	11	0	0	25	25
Va:	Norfolk	<5	< 5	12	14	0	0	15	15
Wash:	Seattle	<5	5	11	11	0	0	25	30
	Spokane	<5	< 5	11	10	0	0	20	25
W. Va:	Charleston	<5	< 5	12	12	0	0	15	10
Wisc:	Milwaukee			8	7	0	0	20	20
Wyo:	Laramie	<5	< 5	7	4	0	0	10	5
Network average		<5	< 5	11	11	0	0	20	20

[a] Barium-140 concentrations for all stations were below the limits of detectability.
[b] Blank indicates that no strontium-89 determinations were made on samples during month.
Note: On April 10, 1967, Southwestern Radiological Health Laboratory began analysing for strontium-90 by the rapid ion exchange method replacing the routine ion exchange method previously used.

scription of the sampling and analytical procedures employed by the PMN appeared in the December 1966 issue of *Radiological Health Data and Reports* (*1*).

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The results for the first quarter of 1967 and April 1967 are presented in table 2. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values were below minimum detectable concentrations (*1*), averages were calculated using one-half the minimum detectable values; however, for iodine–131 and barium–140, zero was used for averaging purposes when concentrations were below minimum detectable levels.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in tables 3 and 4 for April 1966 and November 1966 through April 1967. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

Table 3. Frequency distribution, strontium-90 concentrations in milk at PMN stations, April 1966 and November 1966–April 1967

Strontium-90 (pCi/liter)	Number of stations						
	1966			1967			
	Apr	Nov	Dec	Jan	Feb	Mar	Apr
Under 10	8	19	23	24	21	25	25
10–19	50	40	35	36	38	35	34
20–29	3	4	5	3	4	2	4
30–39	2	0	0	0	0	1	0

Table 4. Frequency distribution of monthly average cesium-137 concentrations in milk at PMN stations, April 1966 and November 1966–April 1967

Cesium-137 (pCi/liter)	Number of stations						
	1966			1967			
	Apr	Nov	Dec	Jan	Feb	Mar	Apr
Under 50	55	61	62	62	62	62	62
50–99	7	2	1	1	1	1	1
100–149	1	0	0	0	0	0	0

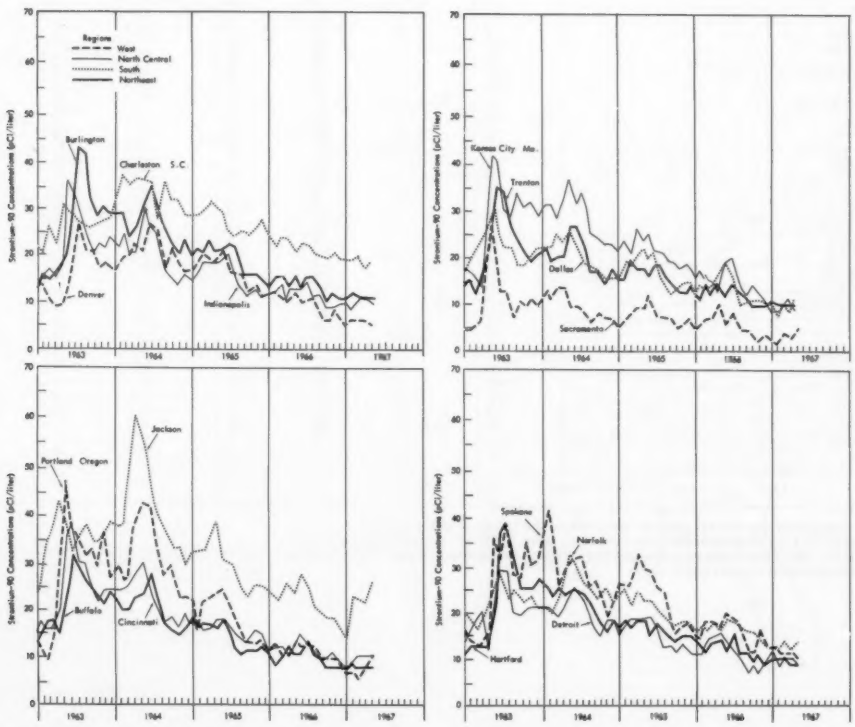

Figure 2. Strontium–90 concentrations in pasteurized milk, 1961–April 1967

2. Canadian Milk Network April 1967 [1]

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calicum and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (*2*).

The April 1967 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

[1] Prepared from May 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 5. Stable elements and radionuclides in Canadian whole milk, April 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.13	1.4	13	34
Edmonton	1.12	1.5	13	40
Ft. William	1.13	1.5	16	44
Fredericton	1.09	1.5	19	46
Halifax	1.15	1.5	17	43
Montreal	1.10	1.5	10	27
Ottawa	1.17	1.6	9	23
Quebec	1.08	1.6	18	49
Regina	1.12	1.5	12	27
St. John's, Nfld.	1.10	1.5	16	51
Saskatoon	1.14	1.4	12	27
Sault Ste. Marie	1.12	1.5	18	38
Toronto	1.16	1.5	7	18
Vancouver	1.14	1.5	19	68
Windsor	1.12	1.5	8	21
Winnipeg	1.09	1.6	10	48
Average	1.12	1.5	13.5	38

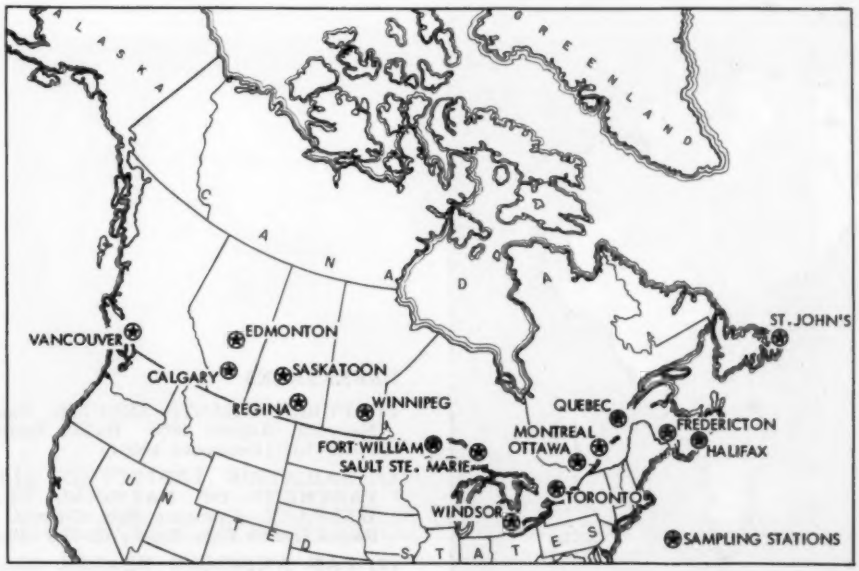

Figure 3. Canadian milk sampling stations

3. Pan American Milk Sampling Program April 1967

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*3*).

Table 6 presents stable potassium, strontium–90, and cesium–137 monthly average concentrations for April 1967.

Table 6. Stable element and radionuclide concentration in PAHO milk, April 1967[a]

Sampling station	Number of samples	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Chile:				
Santiago	4	1.4	4	14
Colombia:				
Bogota	1	1.4	2	< 5
Ecuador:				
Guayaquil	1	1.5	2	< 5
Jamaica:				
Kingston	1	1.5	6	100
Mandeville	NS			
Montego Bay	NS			
Venezuela:				
Caracas	NS			
Canal Zone:				
Cristobal[b]	4		5	35
Puerto Rico:				
San Juan[b]	4		4	15

[a] Iodine-131 and barium-140 determinations were less than 10 pCi/liter for all samples. Strontium-89 was less than 5 pCi/liter for all samples.
[b] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, from the Pasteurized Milk Network are presented.
NS, no sample collected.

Figure 4. Pan American Milk Sampling Program stations

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, August 1966. Radiol Health Data Rep 7:698–701 (December 1966).

(*2*) RADIATION PROTECTION DIVISION, DEPARTMENT OF NATIONAL HEALTH AND WELFARE. Canadian Milk Network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704–705 (December 1966).

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have reached a point of having comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows these States which report milk surveillance actiivties in *Radiological Health Data and Reports*. States having programs appearing in the current issue are highlighted in the figure. A summary of other State programs previously covered, the reporting period, and issue of appearance are as follows.

State milk network	Period covered	Last presented
California	October–December 1966	June 1967
Colorado	January–March 1967	July 1967
Florida	April–June 1966	October 1966
Oklahoma	January–March 1967	July 1967
Oregon	October–December 1966	June 1967
Tennessee	January–March 1967	July 1967
Texas	January–March 1967	July 1967
Washington	October–December 1966	June 1967

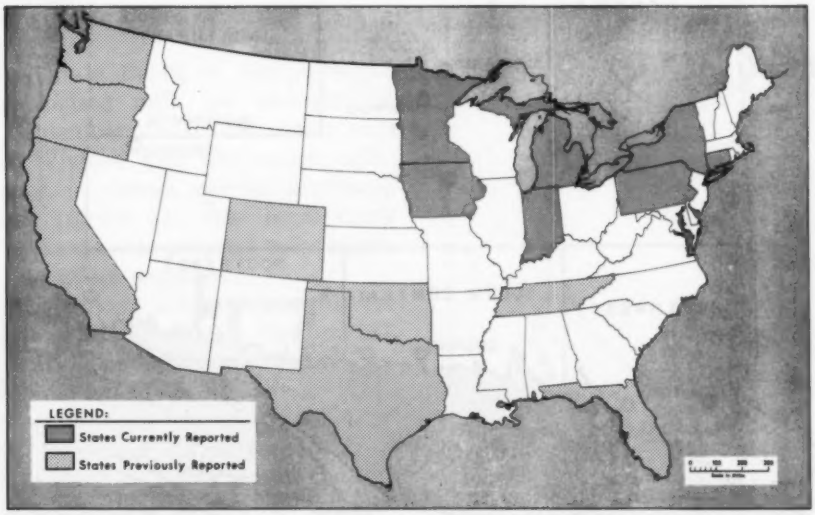

Figure 1. State milk programs reported

1. Connecticut Milk Network January–March 1967

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-ray emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 2). At the present time, weekly samples representative of milk sold in the central area of the State are collected and analyzed for strontium–89, strontium–90, and gamma-ray emitters. Concentrations of iodine–131 are determined as an indication of the presence of radioactivity of recent origin.

Strontium–89 and strontium–90 are determined by chemical separation. Iodine–131 and other gamma-ray emitters are determined by gamma-ray spectroscopy.

The monthly average concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 in central Connecticut pasteurized milk are presented in table 1. These results are presented graphically in figure 3.

Table 1. Radionuclide concentrations in central Connecticut pasteurized milk, January–March 1967

Month 1967	Radionuclide concentration (pCi/liter)			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
January	ND	9	<10	20
February	ND	9	<10	20
March	ND	9	<10	20

ND, below detectable levels.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

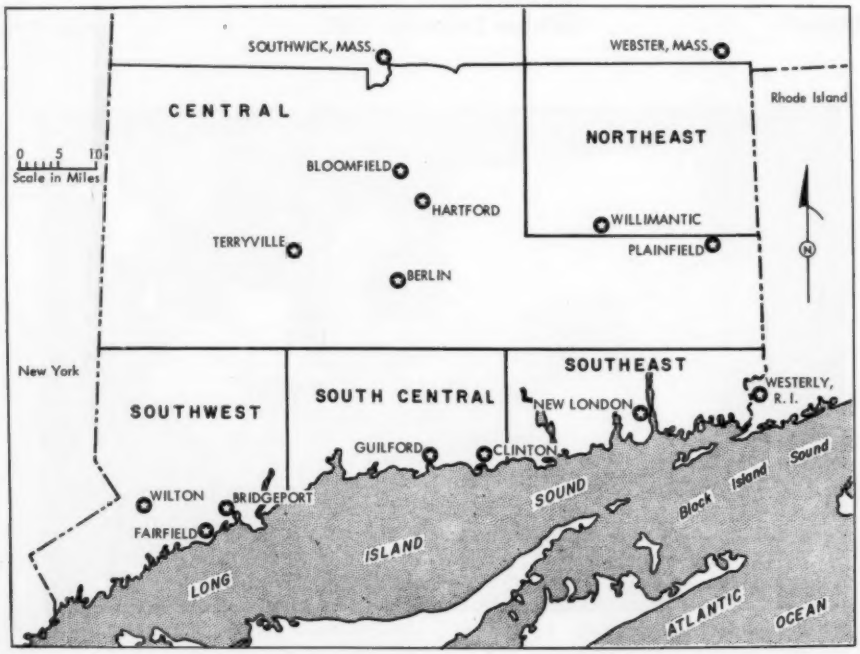

Figure 2. Connecticut pasteurized milk sampling areas

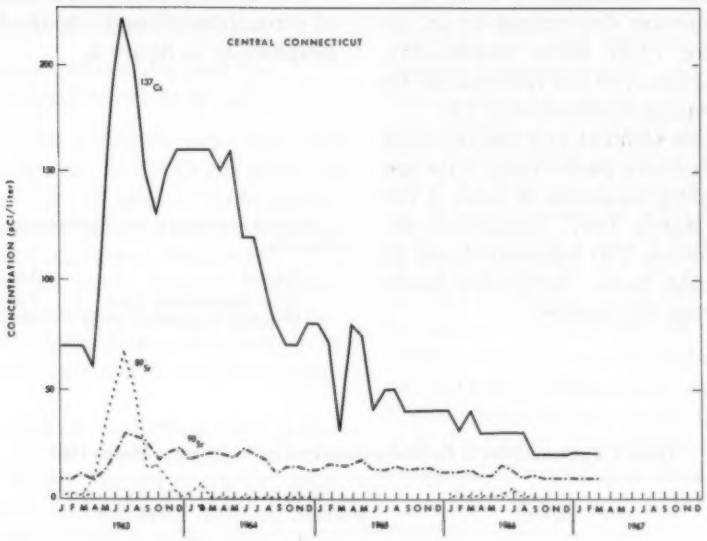
CENTRAL CONNECTICUT
CONCENTRATION (pCi/liter)
200
150
100
50
0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 3. Radionuclide concentrations in central Connecticut pasteurized milk, 1963–March 1967

2. Indiana Milk Network January–March 1967

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. The State was geographically divided into five major milksheds: northeast, northwest, central, southeast, and southwest (figure 4). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are analyzed monthly for strontium–89 and strontium–90. Cesium–137, iodine–131, and barium–140 are determined weekly for at least two of the milksheds. When iodine–131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. From August 1963 to April 1966, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was once a month for the northeast, southeast, and southwest milksheds.

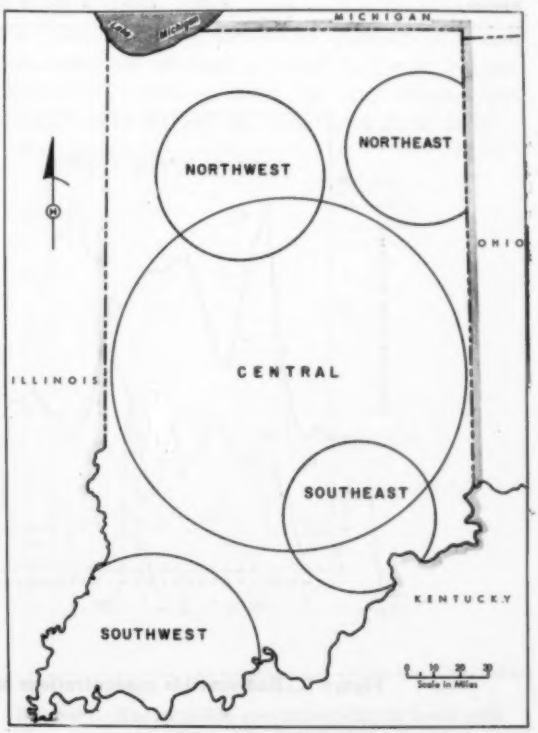

Figure 4. Indiana pasteurized milk sampling areas

Strontium–89 and strontium–90 concentrations in milk samples are determined by an ion exchange procedure (*1,2*) while cesium–137, iodine–131, and barium–140 are determined by gamma-ray scintillation spectrometry (*3*).

The monthly stable element and radionuclide concentrations in Indiana pasteurized milk are presented by sampling locations in table 2 for January through March 1967. Strontium–89, iodine–131, and barium–140 concentrations at all stations remained below detectable levels of 10 pCi/liter during this period.

The monthly network average concentrations of strontium–90 and cesium–137 are presented graphically in figure 5.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

Table 2. Radionuclides in Indiana pasteurized milk, January–March 1967

Sampling location	Calcium (g/liter)			Potassium-40 (pCi/liter)			Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Northeast	1.17	1.16	1.16	1,300	1,290	1,260	9	10	10	15	15	15
Southeast	1.25	1.16	1.17	1,320	1,330	1,320	15	14	13	15	15	15
Central	1.25	1.14	1.16	1,340	1,350	1,340	10	10	10	10	15	10
Southwest	1.23	1.14	1.14	1,280	1,350	1,230	13	12	15	15	15	20
Northwest	1.21	1.18	1.18	1,330	1,380	1,370	12	11	14	15	20	15
Average	1.22	1.16	1.16	1,310	1,340	1,300	12	11	12	15	15	15

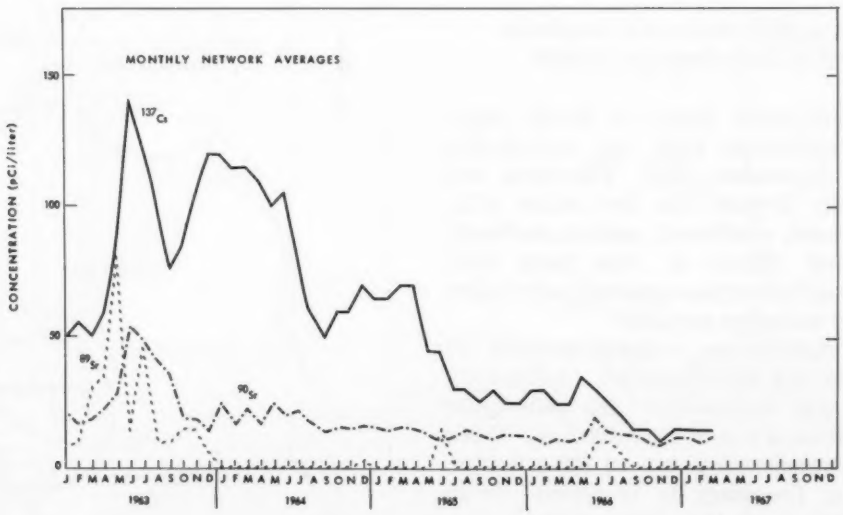
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
150
100
50
0
137Cs
89Sr
90Sr
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 5. Radionuclide concentrations in Indiana pasteurized milk, 1963–March 1967

3. Iowa Milk Network
January 1965–March 1967

State Hygienic Laboratory and the
Iowa State Department of Health

In Iowa, radiological health activities are conducted jointly by the State Department of Health and the State Hygienic Laboratory, with the State Hygienic Laboratory performing the surveillance and analytical functions.

In August 1962 the State Hygenic Laboratory of Iowa began sampling milk for iodine–131. In May 1964 this routine surveillance was expanded to include cesium–137 and strontium–90.

One-gallon samples are collected from 4 stations, selected to give a broad coverage of milk production areas in the State (figure 6). Producers furnishing to the Spencer bottling area are quite restricted to that northwest part of the State and the majority of milk bottled in Iowa City comes from six counties in east central Iowa. The Des Moines shed comprises approximately 60 counties covering about two thirds of the State radiating out of Des Moines in all directions. The Charles City bottling area covers primarily north central Iowa. At present, the Iowa City and Des Moines stations are sampled weekly and the Spencer and Charles City stations are sampled monthly. This sampling frequency is increased when nuclide concentrations warrant closer surveillance. The samples are forwarded to the State Hygienic Laboratory at the University of Iowa, Iowa City for analysis.

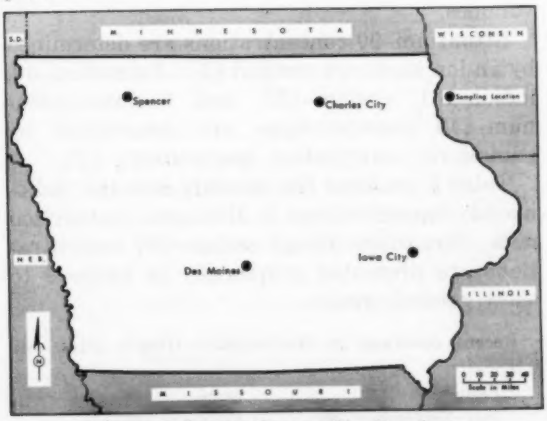

Figure 6. Iowa milk sampling locations

Analytical procedures

Iodine–131 and cesium–137 together with barium-lanthanum–140 and potassium–40 are determined by gamma-scintillation spectrometry using a 4- by 4-inch NaI (Tl) crystal and 512-channel pulse height analyzer. All samples are 3.5 liters and are counted for 80 minutes in Marinelli beakers with ther results being calculated using a 4 by 4 matrix. Strontium–90 is determined by an ion exchange system described by Porter *et al* (*1*). One liter of milk is passed through an ion exchange column; yttrium–90 is eluted from the resin and counted as yttrium oxalate in an automatic low-background proportional counter. Minimum detectable limits are 10 pCi/liter for iodine–131 and cesium–137, and 2 pCi/liter for strontium–90.

Results

Table 3 gives the monthly averages at each of the four locations for January 1965–March 1967, and figure 7 shows graphically the overall network average monthly results for the same period. During this period it can be seen that the concentration levels of cesium–137 and strontium–90 showed a trend to lower values. Iodine–131 was present in any significant amount only during the month of June 1965.

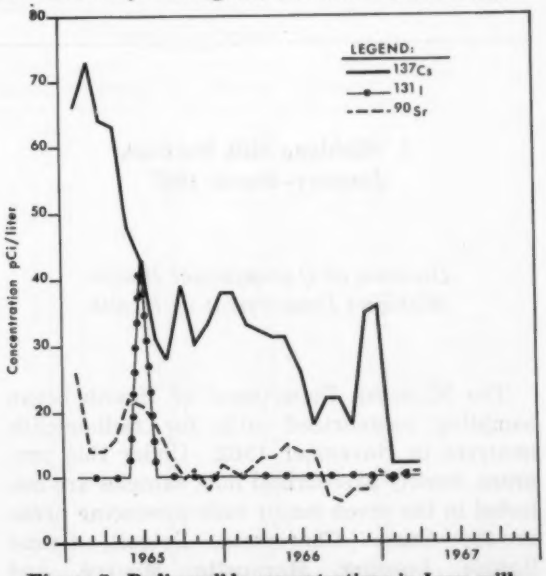

Figure 7. Radionuclide concentrations in Iowa milk January 1965–March 1967

Table 3. Radionuclide concentrations in Iowa milk, January 1965–March 1967

Sampling date	Radionuclide concentration (pCi/liter)											
	Iowa City			Des Moines			Spencer			Charles City		
	Strontium-90	Iodine-131	Cesium-137	Strontium-90	Iodine-131	Cesium-137	Strontium-90	Iodine-131	Cesium-137	Strontium-90	Iodine-131	Cesium-137
1965												
January	22	<10	69	22	<10	71	31	<10	62	29	<10	72
February	18	<10	69	17	<10	78	10	<10	80	12	<10	65
March	14	<10	71	15	<10	72	14	<10	60	12	<10	53
April	20	<10	61	23	<10	62	17	<10	65	23	<10	62
May	25	11	44	21	<10	47	21	<10	47	20	<10	52
June	25	37	38	27	30	45	14	33	41	19	70	49
July	20	<10	29	17	<10	31	16	<10	25	NA	<10	40
August	9	<10	27	14	<10	32	8	<10	23	20	<10	31
September	13	<10	39	11	<10	40	7	<10	38	10	<10	38
October	10	<10	29	10	<10	29	10	<10	29	13	<10	34
November	12	<10	29	9	<10	31	10	<10	36	NA	<10	35
December	13	<10	38	16	<10	46	7	<10	33	NA	<10	36
1966												
January	9	<10	38	18	<10	42	13	<10	45	NA	<10	29
February	11	<10	31	14	<10	37	7	<10	30	NA	NA	NA
March	15	<10	32	19	<10	35	6	<10	29	NA	NA	NA
April	13	<10	29	13	<10	28	13	<10	36	NA	NA	NA
May	26	<10	31	14	<10	38	4	<10	25	NA	NA	NA
June	13	<10	23	15	<10	28	NA	<10	27	NA	NA	NA
July	9	<10	18	19	<10	18	NA	<10	NA	NA	NA	NA
August	5	<10	23	9	<10	20	NA	<10	22	NA	NA	NA
September	5	<10	13	7	<10	21	NA	<10	33	NA	NA	NA
October	6	<10	13	8	<10	21	9	<10	19	NA	NA	NA
November	9	<10	26	7	<10	35	8	<10	34	4	<10	44
December	8	<10	34	6	<10	29	6	<10	33	24	<10	48
1967												
January	11	<10	10	10	12	16	6	<10	10	10	<10	15
February	12	<10	12	8	<10	15	10	<10	12	10	<10	10
March	10	<10	10	10	<10	18	11	<10	10	10	<10	10

NA, no analysis.

4. Michigan Milk Network January–March 1967

Division of Occupational Health
Michigan Department of Health

The Michigan Department of Health began sampling pasteurized milk for radionuclide analyses in November 1962. Under this program, weekly pasteurized milk samples are collected in the seven major milk producing areas in the State: Charlevoix, Detroit, Grand Rapids, Lansing, Marquette, Monroe, and Saginaw (figure 8). Milkshed samples are composited from dairies in proportion to sales volumes.

Strontium–90 concentrations are determined by an ion exchange method (*5*). Potassium–40, iodine–131, cesium–137, and barium-lanthanum–140 concentrations are determined by gamma-ray scintillation spectrometry (*5*).

Table 4 presents the monthly average radionuclide concentrations in Michigan pasteurized milk. Strontium–90 and cesium–137 concentrations are presented graphically in figure 9 to show general trends.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

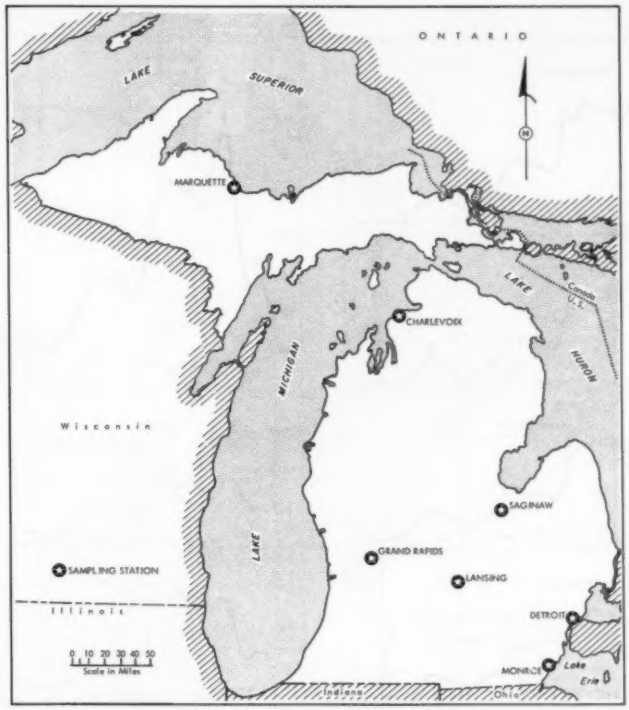

Figure 8. Michigan pasteurized milk network sampling locations

Table 4. Radionuclide concentration in Michigan pasteurized milk, January–March 1967

Sampling location	Month	Radionuclide concentration (pCi/liter)			
		Potassium-40	Strontium-90	Iodine-131	Cesium-137
Charlevoix	January	1,350	7	<14	19
	February	1,310	8	<14	17
	March	1,370	7	<14	17
Detroit	January	1,340	6	<14	14
	February	1,340	6	<14	11
	March	1,350	6	<14	15
Grand Rapids	January	1,330	7	<14	14
	February	1,360	7	<14	18
	March	1,350	6	<14	16
Lansing	January	1,340	6	<14	12
	February	1,340	6	<14	16
	March	1,350	5	<14	14
Marquette	January	NA	NA	NA	NA
	February	NA	NA	NA	NA
	March	1,430	10	<14	37
Monroe	January	1,330	5	<14	9
	February	1,300	4	<14	10
	March	1,320	4	<14	8
Saginaw	January	1,370	6	<14	14
	February	1,320	5	<14	16
	March	1,380	5	<14	13
Average	January	1,340	6	<14	14
	February	1,330	6	<14	15
	March	1,360	6	<14	17

NA, no analysis.

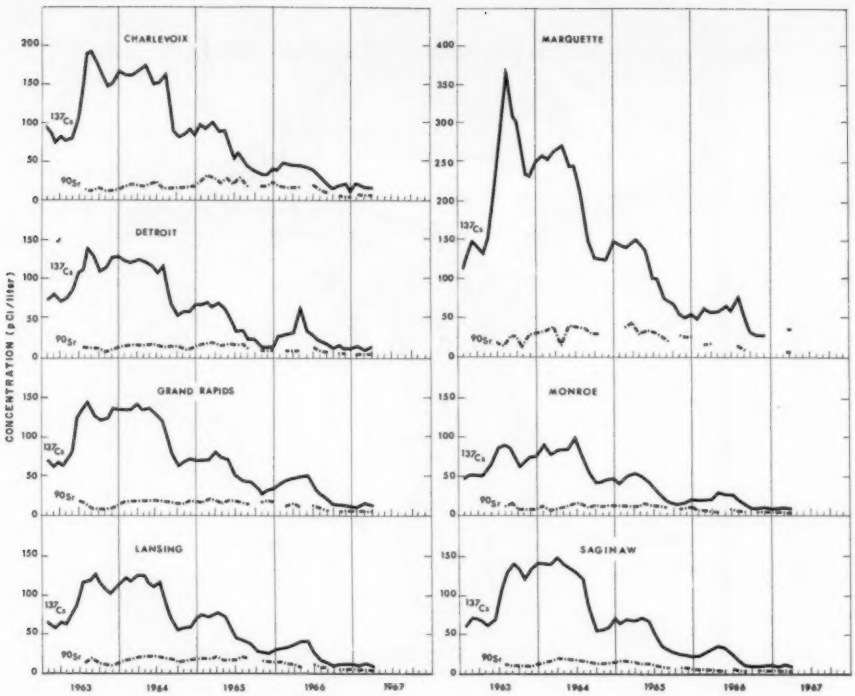

Figure 9. Radionuclide concentrations in Michigan pasteurized milk, 1963–March 1967

5. Minnesota Milk Network January–March 1967

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium–90 concentrations. Presently, monthly samples are collected from eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 10) and analyzed for strontium–90, iodine–131, and cesium–137. One-liter samples of processed Grade A fluid milk are collected at bottling machines in pasteurization plants. The samples are customarily collected in the cities where the Minnesota Health Department district offices are located. However, it is sometimes convenient to collect at other locations. Such samples are considered representative of the district concerned.

Strontium–90 concentrations are determined radiochemically, while iodine–131 and cesium–137 concentrations are determined by gamma-ray spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and the Rural Cooperative Power Association (*6*).

Strontium–90 and cesium–137 concentrations in milk are given for January through March 1967 in table 5, and are presented graphically by milkshed in figure 11 for the period 1961 through March 1967. Iodine–131 concentrations for January through March 1967 were less than 10 pCi/liter in all 24 samples.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

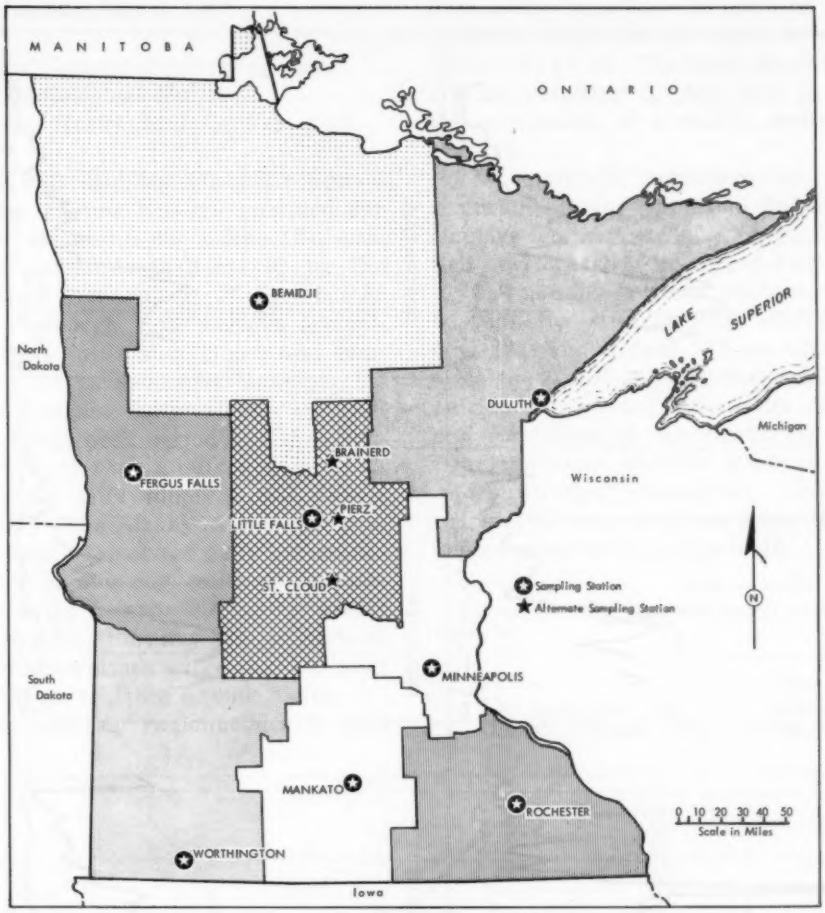

Figure 10. Minnesota milk sampling locations

Table 5. Radionuclide concentrations in Minnesota pasteurized milk, January–March 1967

Sampling location	Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	January	February	March	January	February	March
Bemidji	21	19	20	16	28	39
Mankato	8	9	8	18	21	12
Rochester	9	11	11	17	11	20
Duluth	21	23	24	46	64	47
Worthington	9	10	9	19	9	14
Minneapolis	14	15	15	23	15	42
Fergus Falls	10	11	10	18	9	20
Little Falls	14	13	13	28	14	24
Average	13	14	14	23	21	27

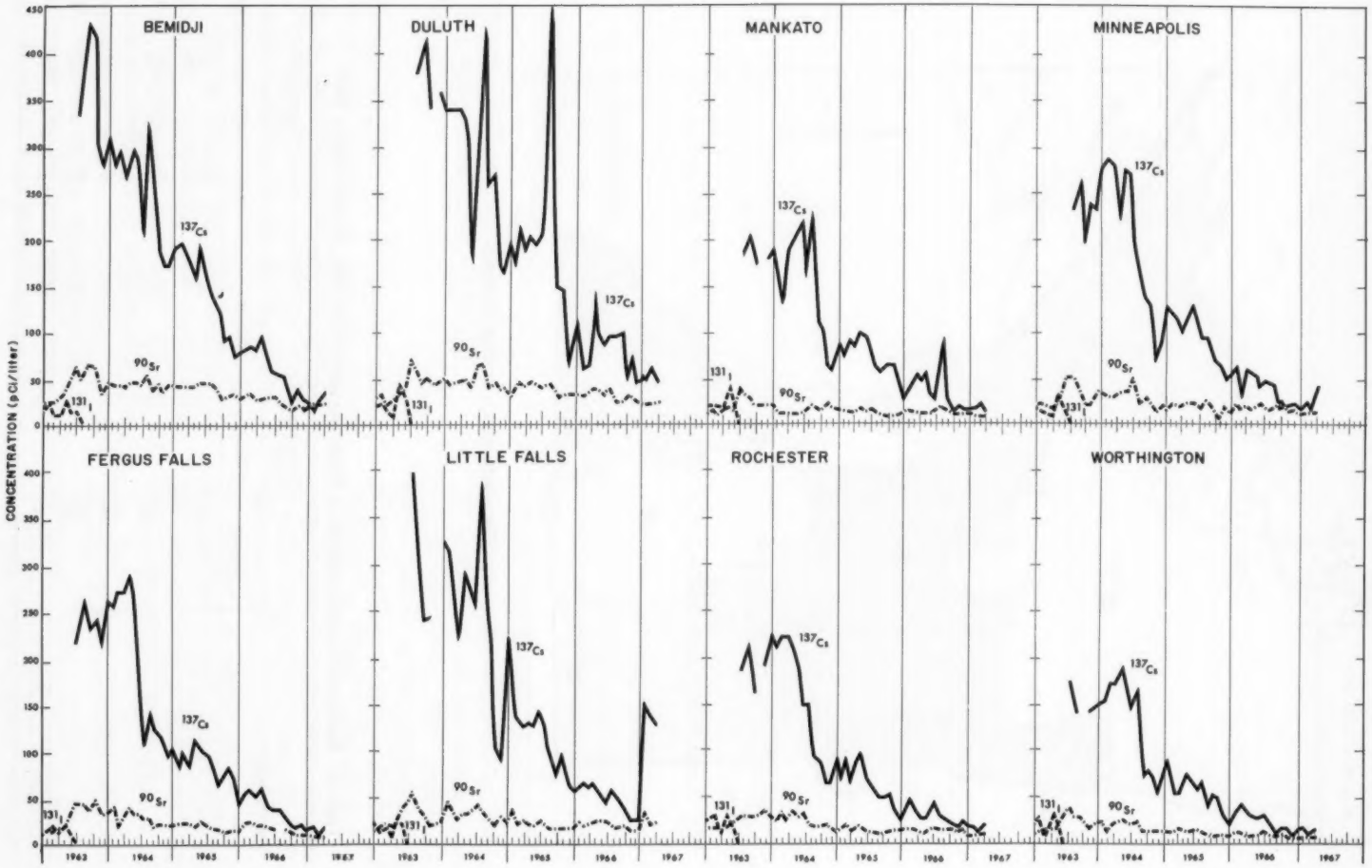

Figure 11. Radionuclide concentrations in Minnesota milk, 1963–March 1967

6. New York Milk Network January–March 1967

Division of General Engineering and Radiological Health
Department of Health, State of New York

Pasteurized milk samples collected routinely from six cities (figure 12) are analyzed for strontium–89, strontium–90, iodine–131, cesium–137 and barium-lanthanum–140 by the New York State Department of Health. At Buffalo and Newburgh, milk samples are collected daily from processing plants and composited weekly for radiochemical analyses. At Messena, and Syracuse daily samples are composited over a two week period and then analyzed. In New York City, a milk sample representing the total milk supply for 1 day is analyzed weekly. The Albany sample, taken at a marketing point, is analyzed daily for iodine–131 and other gamma-ray emitting radionuclides before being composited into a weekly sample. In the event that any sample contains iodine–131 concentrations exceeding 100 pCi/liter, increased surveillance is undertaken.

Gamma-ray emitting radionuclides in milk are determined by scintillation spectrometry. Radioiodine is selectively removed in an anion exchange resin and the resin is analyzed for iodine–131 (*7, 8*). The resin effluent is analyzed and the resulting spectral data is resolved by the application of a matrix method of analysis (*9*).

The analytical procedure for determining strontium–89 and strontium–90 concentrations employs an ion exchange system similar to that developed by Porter and Kahn (*2*).

The monthly average radionuclide concentrations for strontium–89, strontium–90, iodine–131, and cesium–137 are shown in table 6 for the period January through March 1967. During this period, essentially all iodine-131 and strontium–89 concentrations were below their minimum dectable levels of 5 pCi/liter and 3 pCi/liter, respectively. Cesium–137 and iodine–131 concentrations since 1963 are presented graphically in figure 13.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

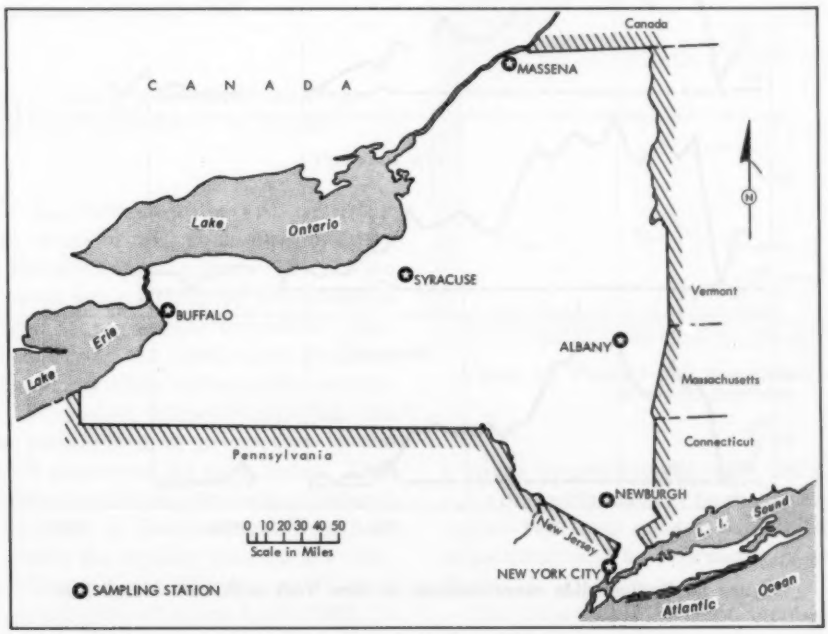

Figure 12. New York milk sampling locations

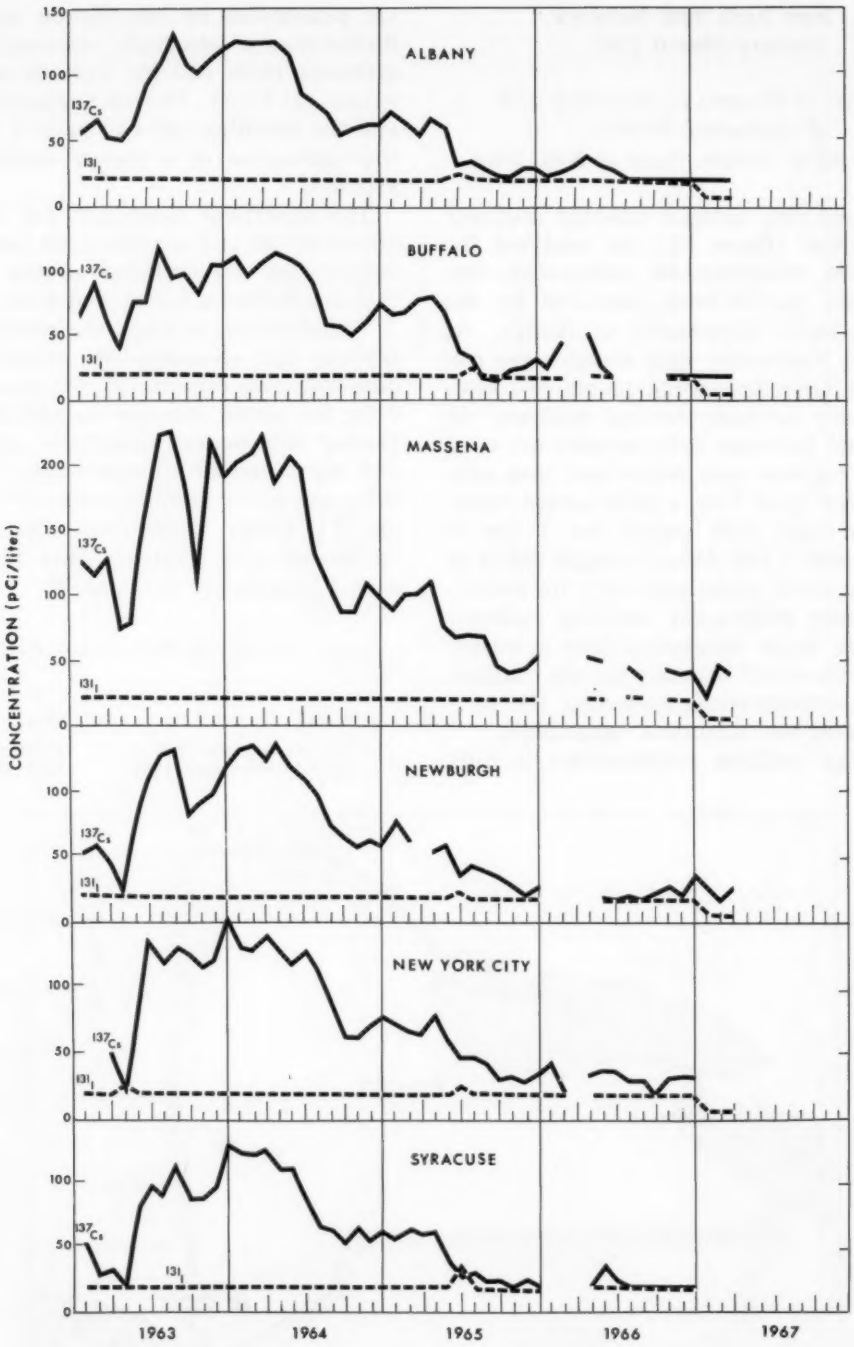

Figure 13. Radionuclide concentrations in New York milk, 1963–March 1967

Table 6. Radionuclide concentrations in New York pasteurized milk, January-March 1967

Sampling location	Month	Radionuclide concentrations (pCi/liter)			
		Strontium-89	Strontium-90	Iodine-131	Cesium-137
Alabany	January	ND	6	ND	ND
	February	ND	7	ND	ND
	March	ND	5	ND	ND
Buffalo	January	ND	5	ND	ND
	February	ND	5	ND	ND
	March	ND	4	ND	ND
Massena	January	ND	8	ND	21
	February	ND	11	ND	48
	March	4	3	ND	43
Newburgh	January	ND	7	ND	26
	February	ND	8	ND	ND
	March	ND	9	ND	30
New York	January	ND	6	ND	ND
	February	ND	7	ND	ND
	March	ND	10	ND	ND
Syracuse	January	NR	NR	NR	NR
	February	NR	NR	NR	NR
	March	NR	NR	NR	NR

ND, not detectable. Detectable limits are: iodine-131, 5 pCi/liter; strontium-89, 3 pCi/liter; strontium-90, 3 pCi/liter; and cesium-137, 20 pCi/liter.
NR, not reported.

7. Pennsylvania Milk Network January–March 1967

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from 10 major milk consumption areas throughout Pennsylvania (figure 14). Two samples per week are collected in Philadelphia and Pittsburgh, while weekly composite samples are collected from the other eight stations. At each sampling location subsamples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the weekly samples are combined for monthly analyses. Strontium–90 analyses have been carried out since April 1963.

The monthly average potassium–40, strontium–90, iodine–131, and cesium–137 concentrations in pasteurized milk are given in table 7. For comparative purposes, strontium–90, iodine–131, and cesium–137 network average concentrations are presented graphically in figure 15.

The chemical separation technique for strontium–90 is essentially an ion exchange method described by Porter *et al* (*1*).

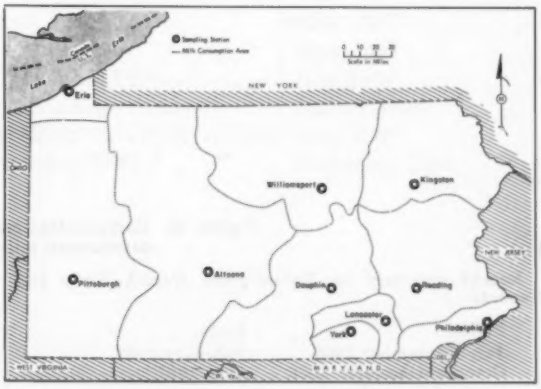

Figure 14. Pennsylvania pasteurized milk network sampling locations

Table 7. Radionuclide concentrations in Pennsylvania pasteurized milk, January–March 1967

Sampling location	Radionuclide concentration (pCi/liter)											
	Potassium-40			Strontium-90			Iodine-131			Cesium-137		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Altoona	860	835	910	15	13	11	<10	<10	<10	17	19	15
Dauphin	820	855	855	10	12	13	<10	<10	<10	14	19	22
Erie	855	940	910	15	12	15	<10	<10	<10	15	18	24
Kingston	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lancaster	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Philadelphia	850	890	875	11	13	9	13	<10	<10	12	19	18
Pittsburgh	830	880	860	14	14	12	12	<10	<10	15	17	19
Reading	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Williamsport	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
York	900	855	890	7	8	9	<10	<10	<10	9	12	17
Average	855	875	885	12	12	12	11	<10	<10	14	17	19

NS, no sample.

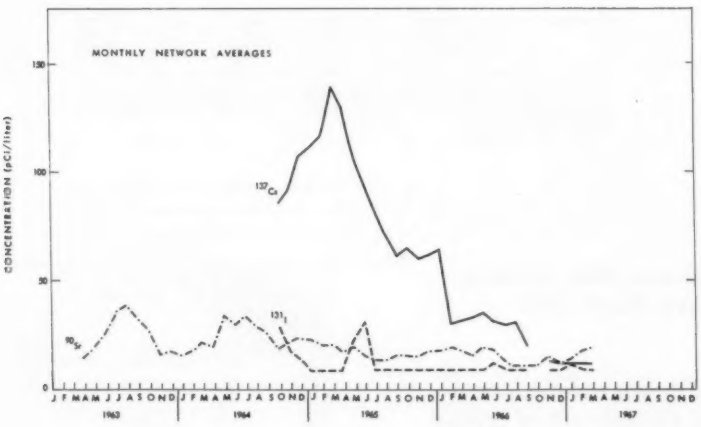
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
150
100
50
0
^{137}Cs
^{131}I
^{90}Sr
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1963
1964
1965
1966
1967

Figure 15. Radionuclide concentrations in Pennsylvania pasteurized milk, 1963–March 1967

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

REFERENCES

(*1*) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Determinations of strontium–90 in milk by an ion exchange method. Anal Chem 33:1306–1308 (September 1961).

(*2*) PORTER, C., and B. KAHN. Improved determinations of strontium–90 in milk by an ion-exchange method. Anal Chem 36:676–678 (March 1964).

(*3*) INDIANA STATE BOARD OF HEALTH, BUREAU OF ENVIRONMENTAL SANITATION. Indiana milk network, April–June 1965. Radiol Health Data 6:612–614 (November 1965).

(*4*) PORTER, C., R. AUGUSTINE, J. MATUSEK, Jr., and M. CARTER. Procedures for determination of stable elements and radionuclides in environmental samples. PHS No. 999–RH–10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

(*5*) MICHIGAN DEPARTMENT OF HEALTH. Michigan milk network, November 1962–December 1964. Radiol Health Data 6:487–492 (September 1965).

(*6*) MINNESOTA DEPARTMENT OF HEALTH AND RURAL COOPERATIVE POWER ASSOCIATION. Survey of environmental radioactivity, January–June 1965. COO–615–17 (August 1965).

(*7*) JOHNSON, R. H. and T. C. REAVEY. Evaluation of ion exchange cartridges for field sampling of iodine–131 in milk. Nature 208:750–752 (November 20, 1965).

(*8*) PORTER, C. R. and M. W. CARTER. Field method for rapid collection of iodine–131 from milk. Public Health Rep 80:453–456 (May 1965).

(*9*) KAHN, B., G. K. MURPHY, C. PORTER, G. R. HAGEE, G. J. KARCHES, and A. S. GOLDIN. Rapid methods for estimating fission product concentrations in milk, PHS Publication No. 999–R–2 (March 1963). Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Food and Diet Surveillance Activities

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Periodically, results from the United Kingdom Diet Survey, conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. Results most recently reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Last presented
California Diet	May–August 1966	May 1967
Connecticut Standard Diet	July–December 1966	May 1967
Institutional Diet, PHS	October–December 1966	July 1967
Teenage Diet, FDA	February–November 1965	August 1966
Tri-City Diet, HASL	May–July 1966	June 1967
United Kingdom Diet	Annual summary 1965	December 1966

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 at 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes remain within the guides recommended by FRC for control action. In the known absence [1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analyses indicate that the concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

Activity	Period reported	Last presented
California Water Sampling Program	January–June 1966	June 1967
Coast Guard Water Sampling Program	1965	November 1966
Minnesota Surface Water Sampling Program	January–June 1966	January 1967
New York Surface Water Sampling Program	June–December 1965	June 1966
Radiostrontium in Tap Water, HASL	March–November 1966	June 1967
Washington Surface Water Sampling Program	July 1964–June 1965	May 1966

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962. PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

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Gross Radioactivity, February 1967, and Strontium-90, October 1965-June 1966, in Surface Waters of the United States

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of Interior

The monitoring of radioactivity in surface waters of the United States was begun in 1957 as a part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Beginning with the establishment of 50 sampling points, this system has been expanded to include 131 stations. These stations are operated jointly with other Federal, State, and local agencies, and with private industries. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological, and radiological analyses. The system provides background information necessary for recognizing water quality trends and for determining current and general levels of surface water contamination and early detection of specific situations which may warrant more detailed evaluation. Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

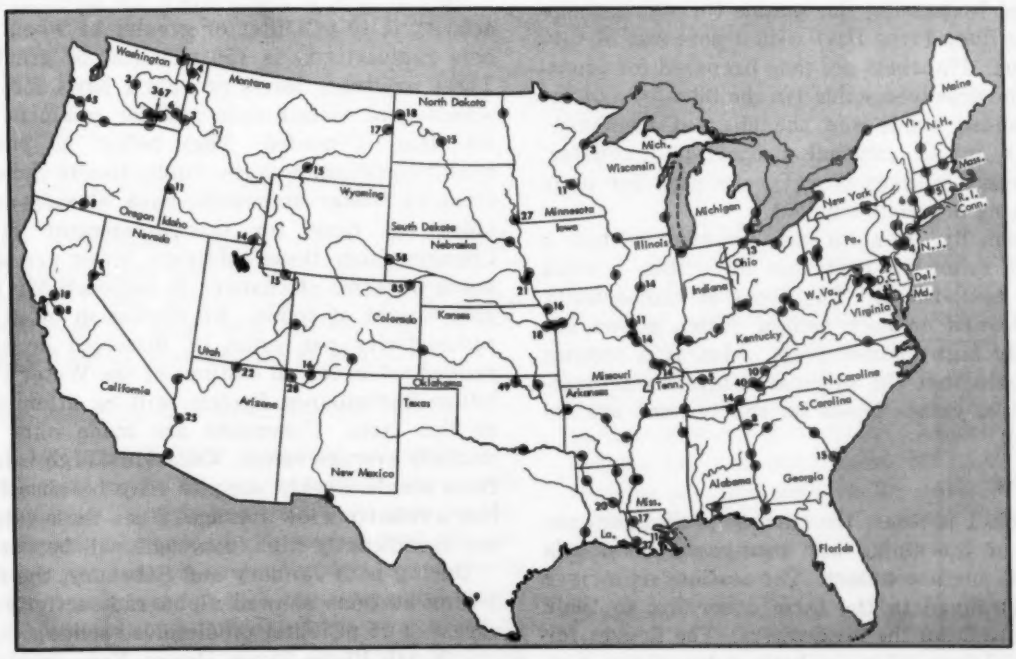

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, February 1967

Sampling procedures

The participating agencies collect 1-liter "grab" samples each week and ship them to the Surveillance System Laboratory in Cincinnati. Presently, gross alpha and beta radioactivity determinations are made either on monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta radioactivity determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are conducted at all newly established stations during the first year of operation. Weekly analyses are also scheduled for selected stations in an effort to detect short-term increases in radioactivity from current or recent nuclear tests or events.

Analytical methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*7*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8 are used for daily checking of the instrument.

Normally, samples are counted within 2 weeks following collection or within 1 week after compositing. The decay of radioactivity is followed on each sample which shows unusually high radioactivity. Also, if a recount indicates that the original analysis was questionable, values based on the recount are recorded.

Results

Table 1 presents the current preliminary results of the alpha- and beta-particle analysis of U.S. surface waters. The stations on a river are arranged in the table according to their distance from the headwaters. The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have zero pCi/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5, the mean is reported as < 1 pCi/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations shown in figure 1, which give the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station.

It has been observed that in water the natural environmental beta radioactivity is usually several times that of the natural environmental alpha radioactivity. Nuclear installations may contribute additional alpha or beta radioactivity whereas fallout contributes primarily additional beta radioactivity. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes (*9*).

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment (*10*). Changes from these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During both January and February, the following stations showed alpha radioactivity in excess of 15 pCi/liter on dissolved solids:

North Platte River, Henry, Neb., and
South Platte River, Julesburg, Colo.

During February, at Morgan City, La., on

Table 1. Radioactivity in raw surface waters, February 1967

Station	Average beta radioactivity (pCi/liter)			Average alpha radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsburgh, Pa.	–	–	–	–	–	–
Animas River:						
Cedar Hill, N. Mex.	7	9	16	1	2	3
Arkansas River:						
Ponca City, Okla.	4	45	49	1	10	11
Atchafalaya River:						
Morgan City, La.	29	8	37	8	2	10
Bear River:						
Preston, Idaho	0	14	14	0	1	1
Big Horn River:						
Hardin, Mont.	2	13	15	1	7	8
Big Sioux River:						
Sioux Falls, S. Dak.	4	23	27	<1	2	2
Clearwater River:						
Lewiston, Idaho	1	2	3	0	0	0
Clinch River:						
Clinton, Tenn.	1	9	10	0	2	2
Kingston, Tenn.[a]	3	37	40	<1	2	2
Colorado River:						
Page, Ariz.	0	22	22	0	5	5
Parker Dam, Calif.-Ariz.	1	24	25	0	5	5
Columbia River:						
Wenatchee, Wash.	0	3	3	0	0	0
Pasco, Wash.[a]	20	347	367	0	1	1
Clatskanie, Ore.	17	48	65	0	<1	<1
Connecticut River:						
Enfield Dam, Conn.	1	4	5	0	0	0
Coosa River:						
Rome, Ga.	4	4	8	1	<1	1
Cumberland River:						
Cheatham Lock, Tenn.	1	4	5	0	0	0
Delaware River:						
Philadelphia, Pa.	1	3	4	0	0	0
Great Lakes:						
Duluth, Minn.	0	3	3	0	0	0
Green River:						
Dutch John, Utah	0	15	15	0	3	3
Hudson River:						
Poughkeepsie, N.Y.	1	5	6	0	0	0
Illinois River:						
Peoria, Ill.	2	12	14	1	2	3
Grafton, Ill.	2	9	11	0	0	0
Kansas River:						
DeSoto, Kans.	1	17	18	0	3	3
Klamath River:						
Keno, Ore.	2	6	8	0	0	0
Maumee River:						
Toledo, Ohio	2	11	13	1	2	3
Mississippi River:						
St. Paul, Minn.	0	11	11	0	0	0
E. St. Louis, Ill.	3	11	14	0	1	1
New Roads, La.	11	6	17	2	0	2
New Orleans, La.	4	7	11	1	0	1
Missouri River:						
Williston, N. Dak.	1	17	18	0	3	3
Bismarck, N. Dak.	<1	15	15	0	3	3
St. Joseph, Mo.	3	13	16	1	3	4
North Platte River:						
Henry, Nebr.	4	54	58	0	38	38
Ohio River:						
Cairo, Ill.	7	7	14	2	1	3
Pend Oreille River:						
Albeni Falls Dam, Idaho	1	3	4	0	0	0
Platte River:						
Plattsmouth, Nebr.	3	18	21	1	6	7
Potomac River:						
Washington, D.C.	0	2	2	0	0	0
Red River, South:						
Alexandria, La.	6	14	20	1	1	2
Rio Grande:						
Laredo, Tex.	2	7	9	0	4	4
Sacramento River:						
Greens Landing, Calif.	2	13	15	1	7	8
San Joaquin River:						
Vernalis, Calif.	3	5	8	0	1	1
San Juan River:						
Shiprock, N. Mex.	18	10	28	5	4	9
Savannah River:						
Port Wentworth, Ga.[a]	4	11	15	<1	0	<1
Snake River:						
Payette, Idaho	2	9	11	0	5	5
Wawawai, Wash.	1	5	6	0	1	1
South Platte River:						
Julesburg, Colo.	18	67	85	5	52	57
Tennessee River:						
Chattanooga, Tenn.	4	10	14	2	2	4
Yellowstone River:						
Sidney, Mont.	4	13	17	0	3	3
Maximum	29	347	367	8	52	57
Minimum	0	2	2	0	0	0

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occuring radionuclides, common to all stations.

the Atchafalaya River, alpha radioactivity dropped to less than 15 pCi/liter on suspended solids. Pasco, Wash., on the Columbia River continued to show beta radioactivity on dissolved solids in excess of 150 pCi/liter.

Strontium–90 determinations and results

Beginning in 1959, strontium–90 analyses of the total solids in surface waters were made on 3-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except at those stations immediately below nuclear installations, where regular quarterly analyses were continued. The method used for determining strontium–90 is a modification of a procedure described by Harley (*8*). Yttrium–90 together with a yttrium carrier is precipitated as yttrium oxalate and the latter is washed, dried, weighted, and counted in a low-background anticoincidence, end-window proportional counter.

Table 2 presents the results of quarterly analyses of strontium–90 concentrations in U.S. surface waters for the fourth quarter of 1965 and the first and second quarters of 1966. The stations are arranged in the table according to their distance from the headwaters. Table 3 presents a summary of these data.

While there are no standards for strontium–90 radioactivity of total solids in surface waters, the Public Health Service Drinking Water Standards set the limit for strontium–90 concentrations in drinking water at 10 pCi/liter.

Table 2. Quarterly strontium-90 concentrations in surface waters, October–December 1965 and January–June 1966

Station	Average concentration (pCi/liter)		
	Oct-Dec 1965	Jan-Mar 1966	Apr-June 1966
Allegheny River:			
Pittsburgh, Pa.	1.0		1.0
Animas River:			
Cedar Hill, N. Mex.		0.8	
Apalachicola River:			
Chattahoochee, Fla.		.9	
Arkansas River:			
Coolidge, Kans.		1.5	
Ponca City, Okla.	2.2		2.4
Fort Smith, Ark.		3.1	2.5
Little Rock, Ark.	2.7		
Pendleton Ferry, Ark.	3.1		2.5
Atchafalaya River:			
Morgan City, La.		1.6	
Bear River:			
Preston, Idaho		1.6	
Big Horn River:			
Hardin, Mont.	1.1		1.7
Big Sioux River:			
Sioux Falls, S. Dak.		2.3	
Chattahoochee River:			
Atlanta, Ga.	1.6		1.1
Lanett, Ala.		1.2	
Columbus, Ga.	1.0		1.0
Chena River:			
Fairbanks, Alaska	0.2		0.4
Clearwater River:			
Lewiston, Idaho		.2	
Clinch River:			
Clinton, Tenn.		.6	
Kingston, Tenn.	1.2	7.3	4.3
Colorado River:			
Loma, Colo.	.8		1.2
Page, Ariz.		3.2	
Boulder City, Nev.	2.7		2.5
Parker Dam, Calif-Ariz.			
Yuma, Ariz.	1.5		2.1
Columbia River:			
Northport Wash.		1.0	
Wenatchee, Wash.	1.4		.3
Pasco, Wash.	1.2		1.2
McNary Dam, Ore.	1.1		2.4
Bonneville, Ore.		.8	
Clatskanie, Ore.	.9		.4
Connecticut River:			
Wilder, Vt.		.9	
Northfield, Mass.	1.0		1.0
Enfield Dam, Conn.		1.0	
Coosa River:			
Rome, Ga.			
Cumberland River:			
Cheatham Lock, Tenn.		1.0	
Cuyahoga River:			
Cleveland, Ohio		1.9	
Delaware River:			
Martins, Creek, Pa.	.8		1.0
Trenton, N. J.		1.1	
Philadelphia, Pa.	.9		1.0
Escambia River:			
Century, Fla.	1.0		.9
Great Lakes:			
Duluth, Minn.	.8		.7
Sault Ste. Marie, Mich.		.8	
Milwaukee, Wis.	.7		1.0
Gary, Ind.		1.7	
Port Huron, Mich.	1.1		1.4
Detroit, Mich.		.6	
Buffalo, N.Y.	2.3		2.3
Green River:			
Dutch John, Utah		2.3	
Hudson River:			
Poughkeepsie, N.Y.	1.8		1.8
Illinois River:			
Peoria, Ill.	1.3		1.7
Grafton, Ill.		2.0	
Kanawha River:			
Winfield Dam, W. Va.		.7	
Kansas River:			
DeSota, Kans.	2.2		2.6
Klamath River:			
Keno, Ore.	1.0		1.3
Little Miami River:			
Cincinnati, Ohio		2.1	
Maumee River:			
Toledo, Ohio	1.8		1.6
Merrimack River:			
Lowell, Mass.		1.9	

Station	Average concentration (pCi/liter)		
	Oct-Dec 1965	Jan-Mar 1966	Apr-June 1966
Mississippi River:			
St. Paul, Minn.		.2	
Dubuque, Iowa	2.4		2.8
Burlington, Iowa		2.1	
E. St. Louis, Ill.	1.9		2.1
Cape Girardeau, Mo.		1.5	
W. Memphis, Ark.	2.0		2.4
Vicksburg, Miss.		1.3	
Delta, La.	2.1		2.2
New Roads, La.	1.8		2.3
New Orleans, La.		2.0	
Missouri River:			
Williston, N. Dak.	2.1		1.8
Bismarck, N.Dak.		1.9	
Yankton, S. Dak.	2.8		2.8
Omaha, Nebr.		2.8	
St. Joseph, Mo.	2.5		3.3
Kansas City, Kans.		2.4	
Missouri City, Mo.	2.7		2.5
St. Louis, Mo.		2.5	
Monongahela River:			
Pittsburgh, Pa.	1.3		1.1
North Platte River:			
Henry, Nebr.	.5		1.7
Ohio River:			
Toronto, Ohio	3.5		1.2
Addison, Ohio		1.3	
Huntington, W.Va.			.9
Cincinnati, Ohio		1.1	
Louisville, Ky.	1.5		1.2
Evansville, Ind.		1.1	
Cairo, Ill.	1.2		1.5
Ouachita River:			
Bastrop, La.		1.9	
Pend Oreille River:			
Albeni Falls Dam, Idaho	.7		.8
Platte River:			
Plattsmouth, Nebr.		1.6	
Potomac River:			
Williamsport, Md.	.7		.7
Great Falls, Md.		1.1	
Washington, D.C.		.5	
Rainy River:			
International Falls, Minn.	3.2		3.0
Baudette, Minn.	3.2		2.7
Raritan River:			
Perth Amboy, N.J. (5 feet below surface) (5 feet above bottom)			
Red River, North:			
Grand Forks, N. Dak.	5.8	5.6	6.0
Red River, South:			
Denison, Tex.		4.6	
Index, Ark.	4.0		4.2
Bossier City, La.			
Alexandria, La.	2.9		2.2
Rio Grande:			
Alamosa, Colo.	.5		1.5
El Paso, Tex.			
Laredo, Tex.	1.3		1.7
Brownsville, Tex.		1.6	
Roanoke River:			
John H. Kerr Resr. Dam, Va.	1.5		1.2
Sabine River:			
Ruliff, Tex.		1.4	
Sacramento River:			
Greens Landing, Calif.		.5	
St. Lawrence River:			
Massena, N. Y.		1.7	
San Joaquin River:			
Vernalis, Calif.	.6		1.6
San Juan River:			
Shiprock, N. Mex.	1.5		1.2
Savannah River:			
North Augusta, S.C.		.9	
Port Wentworth, Ga.	1.4	1.2	2.2
Schuylkill River:			
Philadelphia, Pa.		.9	
Shenandoah River:			
Berryville, Va.	.4		.5
Ship Creek:			
Anchorage, Alaska		.1	
Snake River:			
Payette, Idaho	.5		.5
Wawawai, Wash.	.4		.4
Ice Harbor Dam, Wash.		.5	
South Platte River:			
Julesburg, Colo.	1.6		

Table 2. Quarterly strontium-90 concentrations in surface waters, October–December 1965 and January–June 1966—Continued

Station	Average concentration (pCi/liter)			Station	Average concentration (pCi/liter)		
	Oct-Dec 1965	Jan-Mar 1966	Apr-June 1966		Oct-Dec 1965	Jan-Mar 1966	Apr-June 1966
Spokane River:				Truckee River:			
Post Falls Dam, Idaho		.6		Farad, Calif	.9		.8
Susquehanna River:				Verdigris River:			
Sayre, Pa		.9		Nowata, Okla	3.6		
Conowingo, Md			1.0	Wabash River:			
Tennessee River:				New Harmony, Ind	.9		1.7
Lenoir City, Tenn	.8			Willamette River:			
Chattanooga, Tenn	1.0	.9	1.0	Portland, Ore	.2		.1
Bridgeport, Ala			.7	Yakima River:			
Pickwick Landing, Tenn		1.0		Richland, Wash		.3	
Tombigbee River:				Yellowstone River:			
Columbus, Miss		1.4		Sidney, Mont		1.3	

During the fourth quarter of 1965 and the first and second quarters of 1966, this standard was not exceeded. Comparison between the quarters is not feasible at all sampling locations because of fluctuations in sampling frequencies. Comparison with results prior to October 1964 should take into consideration an instrument recalibration which resulted in a lowering of strontium–90 values by 15 percent (*11*).

Table 3. Summary of strontium-90 in surface waters October–December 1965 and January–June 1966

Period	Total number of samples	Concentration (pCi/liter)			
		Maximum	Miminum	Median	Average
October-December 1965	69	[a]5.8±0.4	[a]0.2±0.1	1.2	1.6
January-March 1966	62	7.3± .4	.1± .1	1.2	1.3
April-June 1966	66	6.0± .6	.1± .1	1.5	1.6

[a] Two standard deviations counting error.

The highest result for the fourth quarter 1965 and the second quarter 1966 and the second highest result for the first quarter 1966 occurred at Grand Forks, N. Dak., on the Red River, North. The highest result for the first quarter was at Kingston, Tenn., on the Clinch River. This result (7.3 pCi/liter) is a weighted average of three results (31.8, 15.0, and 3.4 pCi/liter). The reason for these three determinations was the occurrence of an unusually high gross beta radioactivity (*12*) during this quarter. This value was very unusual for this station. The effectiveness and importance of monitoring the gross radioactivities are illustrated since there was no other indication of elevated strontium–90 concentrations. According to the Atomic Energy Commission, these high values were the result of a temporary low flow caused by a reservoir cleaning operation.

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Radioactivity in Washington Surface Water July 1965–June 1966 [1]

Washington State Department of Health

Radioanalysis of surface water samples collected throughout the State of Washington is one of the major functions of the Washington State Department of Health radiation surveillance program. Most surface water samples are collected quarterly or semiannually by the Washington Pollution Control Commission from 71 stations located on 56 rivers throughout the State. Selected stations on the Columbia River are sampled weekly or monthly by local health departments. Cedar River, a major water supply for the greater Seattle area, is sampled monthly by the City of Seattle Water Department.

All surface water samples are collected as grab samples in 2-liter polyethylene bottles. To prevent loss of radioactivity to the container, 2 milliliters of concentrated nitric acid are added to the sample before shipment to the Washington State Department of Health laboratory in Seattle for analysis.

Analytical procedures

Surface water samples are divided into two groups; those samples coming from the Columbia River and those samples coming from waters other than the Columbia River. The latter samples are placed in stainless-steel Marinelli beakers for gamma-ray spectroscopy analysis as soon after receipt as possible. Distilled water is added when necessary to obtain a standardized counting geometry of 2 liters. Table 1 gives the gamma-ray efficiencies and detection limits for the gamma-ray spectrometer. After gamma-ray analysis, the samples are filtered through Whatman No. 42 filter paper. The filter paper containing the suspended solids is ashed in a muffle furnace, transferred to a tared planchet, weighed, and

[1] Summarized from "Environmental Radiation Surveillance in Washington State," Fifth Annual Report, December 1966.

Table 1. Beta-particle and gamma-ray efficiencies and detectability limits for the Washington State analysis

Radionuclide	Energy band (MeV)	Efficiency (percent)	Average background (cpm)	Detectability limits (pCi)
Beta particle				
Strontium-90–yttrium-90		34	0.7	[a]0.31
Yttrium-90		38	.7	[a] .28
Phosphorus-32		35	.7	[a] .30
Gamma-ray				
Chromium-51	0.30–0.36	0.50	23.56	[b]200
Ruthenium-106	.44– .56	.91	23.03	[b]100
Cesium-137	.62– .72	2.50	11.57	[b]30
Zirconium-95	.73– .79	4.40	5.87	[b]20
Zinc-65	1.05–1.17	.98	6.47	[b]50

[a] Amount of radioactivity necessary to produce a net cpm equal to 2σ of background, based on 100-minute counts.

[b] Amount of radioactivity necessary to produce a net cpm equal to 4σ of the respective background, based on 100-minute counts. These detectability limits are given in pCi. To convert to pCi/liter, the volume of the sample must be taken into consideration.

counted for gross beta radioactivity. The filtrate is evaporated to near dryness, quantitatively transferred to a tared planchet, dried, weighed, and counted for gross beta radioactivity.

Columbia River water is analyzed for gamma-ray activity approximately 14 days after collection. This delay allows the short-lived radionuclides, sodium–24, arsenic–76 and neptunium–239, to decay, leaving a less complex spectrum which can be evaluated without computer assistance. Following gamma-ray analysis the Columbia River samples are divided into two aliquots for further analysis. One aliquot is prepared for phosphorus–32 analysis and the other is analyzed for gross beta radioactivity by the methods described above. Gross beta-particle counting for all samples is performed 18 days after collection.

The phosphorus–32 analysis, a modification of published methods (*1–4*), begins 15 days after sample collection to allow arsenic–76 and other short-lived radionuclides to decay. The phosphorus is separated from interfering nuclides by precipitation as ammonium phosphomolybdate from an acid medium. The precipitate is washed with ammonium nitrate, dissolved with 3*N* ammonium hydroxide, transferred to a tared planchet, dried, ashed at 450° C., and counted for beta radioactivity.

Results

Table 2 presents the monthly average results for the Columbia River stations which are sampled routinely. In averaging, a less-than value is assumed to be equal to its numerical value and a less-than sign is placed in front of the average.

Table 3 summarizes the beta radioactivity measurements from the 63 other surface water stations from July 1965 through June 1966. The second column in this table gives code numbers and the abbreviations denoting geographical sections (figure 1). Each river is assigned a four digit number; the first two digits

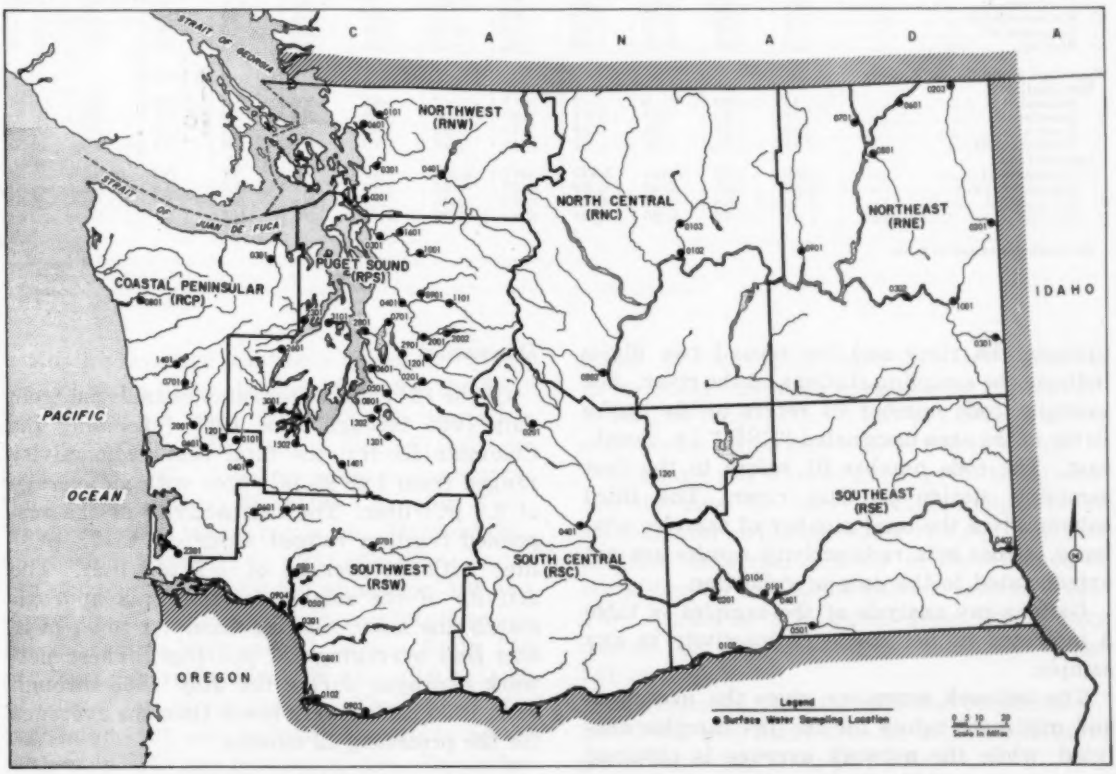

Figure 1. Washington surface water sampling locations with code numbers

Table 2. Monthly average radioactivity in Columbia River water, July 1965–June 1966

Location and type of analysis	Concentration (pCi/liter)											
	1965						1966					
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Richland (Code No. RSE 0104)												
Beta-particle												
Suspended [a]	12	50	1,805	94	26	34	18	17	31	41	21	28
Dissolved [a]	49	63	881	234	246	189	168	222	265	224	96	136
Total [a]	61	113	2,686	328	272	223	186	239	296	265	117	164
Phosphorus-32 [b]	67	46	1,234	330	164	283	166	307	315	318	116	62
Gamma-ray [b]												
Chromium-51	2,674	2,814	11,635	9,060	8,377	7,438	7,530	8,793	7,917	13,650	2,958	1,716
Ruthenium-106 [c]	< 75	<100	<102	<117	155	123	<122	<100	<100	158	<100	<100
Zirconium-95	< 15	< 20	< 16	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Zinc-65	70	122	244	328	152	244	192	338	310	546	140	123
Pasco (Code No. RSE 0101)												
Beta-particle												
Suspended [a]	17	19	40	57	38	45	18	21	28	53	NS	20
Dissolved [a]	30	75	57	138	169	137	96	197	172	264	NS	21
Total [a]	47	94	97	195	207	182	114	218	200	317	NS	41
Phosphorus-32 [b]	NS	57	58	151	233	198	119	284	226	407	NS	18
Gamma-ray [b]												
Chromium-51	1,905	2,549	5,026	7,279	5,883	4,680	4,318	7,083	4,857	8,491	NS	319
Ruthenium-106 [c]	< 50	60	< 50	< 50	75	< 50	< 50	78	76	82	NS	< 50
Zirconium-95	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	NS	< 10
Zinc-65	74	87	87	129	142	246	138	308	323	335	NS	75
McNary Dam (Code No. RSE 0102)												
Beta-particle												
Suspended [a]	NS	NS	19	NS	NS	14	NS	NS	10	NS	NS	10
Dissolved [a]	NS	NS	37	NS	NS	56	NS	NS	80	NS	NS	23
Total [a]	NS	NS	56	NS	NS	70	NS	NS	90	NS	NS	33
Phosphorus-32 [b]	NS	NS	41	NS	NS	69	NS	NS	110	NS	NS	26
Gamma-ray [b]												
Chromium-51	NS	NS	3,064	NS	NS	2,253	NS	NS	2,816	NS	NS	877
Ruthenium-106 [c]	NS	NS	< 50	NS	NS	55	NS	NS	< 50	NS	NS	78
Zirconium-95	NS	NS	< 10	NS	NS	< 10	NS	NS	< 10	NS	NS	< 10
Zinc-65	NS	NS	< 25	NS	NS	52	NS	NS	138	NS	NS	61
Washougal (Code No. RSW 0903)												
Beta-particle												
Suspended [a]	15	NS	8	7	8	7	NS	NS	NS	NS	NS	NS
Dissolved [a]	17	NS	21	31	37	32	NS	NS	NS	NS	NS	NS
Total [a]	32	NS	29	38	45	39	NS	NS	NS	NS	NS	NS
Phosphorus-32 [b]	14	NS	19	27	46	40	NS	NS	NS	NS	NS	NS
Gamma-ray [b]												
Chromium-51	960	NS	2,141	2,122	1,918	2,178	NS	NS	NS	NS	NS	NS
Ruthenium-106 [c]	< 50	NS	< 50	< 50	< 50	< 50	NS	NS	NS	NS	NS	NS
Zirconium-95	< 10	NS	< 10	< 10	< 10	< 10	NS	NS	NS	NS	NS	NS
Zinc-65	43	NS	< 25	< 25	< 25	< 25	NS	NS	NS	NS	NS	NS

See footnotes at end of table.

indicate the river and the second two digits indicate the sampling stations on the river. For example, code number 04 refers to the Snake River in the area designated "RSE," i.e., Southeast. The code number 01 refers to the first sampling station on that river. The third column gives the total number of samples analyzed. Gross beta radioactivity results are not extrapolated to the date of collection.

Gamma-ray analysis of the samples in table 3 indicated no detectable radioactivity in any sample.

The network summary gives the maximum and minimum values for the 184 samples analyzed, while the network average is obtained by averaging all the station average values.

Discussion

Of the 184 river water samples analyzed from July 1965 through June 1966 (excluding the Columbia River), the total beta radioactivity ranged from 1 to 95 pCi/liter with an average of 3.8 pCi/liter. The radioactivity of the suspended fraction ranged from <1 to 78 pCi/liter with an average of <1 pCi/liter. The activity of the soluble fraction was approximately the same, ranging from <1 to 17 pCi/liter and averaging 2.4 pCi/liter. These network averages during the July 1965 through June 1966 period were lower than the averages for the preceding 12 months.

Table 2. Monthly average radioactivity in Columbia River water, July 1965–June 1966—Continued

Location and type of analysis	Concentration (pCi/liter)											
	1965						1966					
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Northport (Code No. RNE 0601)												
Beta-particle												
Suspended [a]	< 1	NS	< 1	NS	NS	< 1	NS	NS	< 1	NS	NS	1
Dissolved [a]	2	NS	5	NS	NS	3	NS	NS	3	NS	NS	3
Total [a]	< 3	NS	< 6	NS	NS	< 4	NS	NS	< 4	NS	NS	4
Phosphorus-32 [b]	< 1	NS	< 1	NS	NS	< 1	NS	NS	< 1	NS	NS	< 1
Gamma-ray [b]												
Chromium-51	<100	NS	<100	NS	NS	<100	NS	NS	<100	NS	NS	<100
Ruthenium-106 [c]	< 50	NS	< 50	NS	NS	< 50	NS	NS	< 50	NS	NS	< 50
Zirconium-95	< 10	NS	< 10	NS	NS	< 10	NS	NS	< 10	NS	NS	< 10
Zinc-65	< 25	NS	< 25	NS	NS	< 25	NS	NS	< 25	NS	NS	< 25
Wanapum Dam (Code No. RSC 1201)												
Beta-particle												
Suspended [a]	NS	NS	NS	NS	NS	NS	NS	NS	< 1	< 1	< 1	< 1
Dissolved [a]	NS	NS	NS	NS	NS	NS	NS	NS	3	3	3	3
Total [a]	NS	NS	NS	NS	NS	NS	NS	NS	< 4	< 4	< 4	< 4
Phosphorus-32 [b]	NS	NS	NS	NS	NS	NS	NS	NS	< 1	< 1	< 1	< 1
Gamma-ray [b]												
Chromium-51	NS	NS	NS	NS	NS	NS	NS	NS	<100	<100	<100	<100
Ruthenium-106 [c]	NS	NS	NS	NS	NS	NS	NS	NS	< 50	< 50	< 50	< 50
Zirconium-95	NS	NS	NS	NS	NS	NS	NS	NS	< 10	< 10	< 10	< 10
Zinc-65	NS	NS	NS	NS	NS	NS	NS	NS	< 25	< 25	< 25	< 25
Vancouver (Code No. RSW 0102)												
Beta-particle												
Suspended [a]	11	NS	9	8	9	9	8	12	8	11	15	12
Dissolved [a]	16	NS	22	29	34	27	28	40	33	31	29	14
Total [a]	27	NS	31	37	43	36	36	52	41	42	44	26
Phosphorus-32 [b]	14	NS	18	24	44	32	40	49	44	47	33	14
Gamma-ray [b]												
Chromium-51	985	NS	2,117	2,137	1,896	1,388	1,560	1,907	1,524	1,551	1,195	638
Ruthenium-106 [c]	< 50	NS	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Zirconium-95	< 10	NS	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Zinc-65	42	NS	< 25	< 25	< 25	< 25	43	59	57	50	93	64
Longview (Code No. RSW 0904)												
Beta-particle												
Suspended [a]	NS	NS	NS	NS	NS	NS	NS	NS	NS	8	6	6
Dissolved [a]	NS	NS	NS	NS	NS	NS	NS	NS	NS	19	18	11
Total [a]	NS	NS	NS	NS	NS	NS	NS	NS	NS	27	24	17
Phosphorus-32 [b]	NS	NS	NS	NS	NS	NS	NS	NS	NS	24	14	11
Gamma-ray [b]												
Chromium-51	NS	NS	NS	NS	NS	NS	NS	NS	NS	836	609	453
Ruthenium-106 [c]	NS	NS	NS	NS	NS	NS	NS	NS	NS	< 50	< 50	< 50
Zirconium-95	NS	NS	NS	NS	NS	NS	NS	NS	NS	< 10	< 10	< 10
Zinc-65	NS	NS	NS	NS	NS	NS	NS	NS	NS	< 27	< 25	< 36

[a] Activity at time of counting. Strontium-90 yttrium-90 calibration standard.
[b] Results extrapolated to date of sample collection.
[c] Net activity in the 0.44–0.56 MeV gamma-ray range is assumed to be only ruthenium-106.
NS, no sample reported.

Monthly average total beta radioactivity for the Columbia River stations below the Hanford Facility ranged from 17 to 328 pCi/liter with one exception which was 2,686 pCi/liter in September 1965. Monthly average concentrations of phosphorus–32 in the Columbia River water samples taken below the Hanford Facility ranged from 11 to 1,234 pCi/liter.

The gamma-ray emitters, ruthenium–106 and zirconium–95, were found in monthly average concentrations that ranged from <50 to 158 pCi/liter for ruthenium–106 and <10 to <20 pCi/liter for zirconium–95. The values for ruthenium–106 are probably a combination of ruthenium–103 and ruthenium–106. Two other radionuclides, chromium–51 and zinc–65, were found in detectable quantities in Columbia River water. Monthly averages for chromium–51 ranged from 11 to 13,650 pCi/liter, and for zinc–65 the range was <25 to 546 pCi/liter.

Although any standards for gross beta radioactivity must be very carefully applied, the standard for drinking water is 1,000 pCi/liter of gross beta radioactivity in the absence of strontium–90 and alpha-particle emitters (*5*). The standards for water from all dietary sources for the general population at large (*6*) are:

Chromium–51, 670,000 pCi/liter; ruthenium–106, 3,300 pCi/liter; zinc–65, 10,000 pCi/liter; phosphorus–32, 7,000 pCi/liter.

Table 3. Beta radioactivity in Washington surface water (except for Columbia River) July 1965–June 1966

Sampling location	Code number	Number of samples	Concentration (pCi/liter)								
			Suspended [a]			Dissolved [a]			Total		
			Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Baker River	RNW 0401	1	< 1			3			4		
Cedar River	RPS 0201	12	< 1	< 1	< 1	< 1	<1	3	1	1	4
Chehalis River	RSW 0601	2	< 1	< 1	< 1	1	<1	1	2	2	2
	RCP 0401	1	< 1			1			2		
Chico Creed	RPS 3101	4	< 1	<1	< 1	2	2	3	3	3	4
Cloquallam River	RCP 0101	2	< 1	<1	< 1	1	1	1	1	2	2
Colville River	RNE 0801	3	< 1	<1	< 1	4	3	5	5	4	6
Coweman River	RSW 0501	2	< 1	<1	< 1	5	2	8	6	3	9
Cowlitz River	RSW 0701	4	< 1	<1	< 1	2	<1	2	2	1	3
Deschutes River	RPS 1502	2	< 1	<1	< 1	2	1	2	2	2	3
Dosewallips River	RPS 2301	1	< 1			< 1			1		
Dungeness River	RCP 0301	1	< 1			1			2		
Duwamish River	RPS 0601	2	< 1	<1	< 1	2	2	2	3	3	3
Goldsborough Creek	RPS 3001	1	< 1			2			3		
Green River	RPS 0501	2	< 1	<1	< 1	< 1	<1	1	1	1	2
Hamma Hamma River	RPS 2601	1	< 1			< 1			1		
Hoh River	RCP 0801	1	< 1			1			2		
Humptulips River	RCP 0701	2	< 1	<1	< 1	1	<1	1	1	1	2
Issaquah Creek	RPS 2901	2	< 1	<1	< 1	2	2	2	3	3	3
Kalama River	RSW 0301	2	< 1	<1	< 1	< 1	<1	1	1	1	2
Kettle River	RNE 0701	3	< 1	<1	< 1	2	2	2	3	3	3
Lake Washington	RPS 2801	1	< 1			6			7		
Lake Whatcom	RNW 0601	8	< 1	<1	3	4	3	5	5	4	6
Lewis River	RSW 0801	6	[b] < 1	<1	< 1	1	<1	2	2	1	3
Little Spokane River	RNE 1001	2	1	<1	2	5	3	6	6	4	8
Naches River	RSC 0401	5	< 1	<1	< 1	1	1	1	2	2	2
Naselle River	RCP 2201	6	[b] < 1	<1	2	< 1	<1	2	2	1	4
Newaukum River	RSW 0401	2	< 1	<1	< 1	1	1	1	2	2	2
Nisqually River	RPS 1401	4	< 1	<1	< 1	2	1	2	2	2	3
Nooksack River	RNW 0101	4	1	<1	2	3	2	4	4	3	6
North Fork, Stillaguamish River	RPS 1601	2	< 1	<1	< 1	3	2	4	4	3	5
Okanogan River	RNC 0102	2	1	<1	2	3	2	3	4	4	4
	RNC 0103	1	< 1			3			4		
Pend Oreille River	RNE 0201	3	< 1	<1	1	3	3	3	4	4	4
	RNE 0203	2	< 1	<1	< 1	4	3	4	4	4	5
Puyallup River	RPS 1301	2	39	1	[c] 78	10	2	17	49	3	95
	RPS 1302	6	2	<1	5	2	1	3	3	2	7
Quinault River	RCP 1401	1	< 1			1			2		
Samish River	RNW 0301	2	< 1	<1	< 1	2	2	2	3	3	3
Sammamish River	RPS 0701	1	< 1			2			3		
Sanpoil River	RNE 0901	4	< 1	<1	< 1	2	2	2	3	3	3
Satsop River	RCP 1201	4	< 1	<1	< 1	< 1	<1	1	1	1	2
Skagit River	RNW 0201	6	< 1	<1	< 1	2	2	2	3	3	3
Skykomish River	RPS 1101	2	< 1	<1	< 1	4	2	5	4	3	6
Snake River	RSE 0401	4	< 1	<1	1	4	3	5	5	4	6
	RSE 0402	4	1	<1	3	5	3	6	6	4	9
Snohomish River	RPS 0401	4	< 1	<1	< 1	2	2	2	3	3	3
Snoqualmie River	RPS 1201	2	< 1	<1	< 1	3	2	3	3	3	4
South Fork, Stillaguamish River	RPS 1001	2	< 1	<1	< 1	3	2	4	4	3	5
Spokane River	RNE 0301	2	< 1	<1	< 1	3	2	3	3	3	4
	RNE 0302	3	2	<1	4	3	2	4	5	3	8
Stillaguamish River	RPS 0301	2	< 1	<1	< 1	2	2	2	3	3	3
Sultan River	RPS 0901	4	< 1	<1	< 1	3	1	5	4	2	6
Tolt River	RPS 2001	4	< 1	<1	< 1	2	<1	5	2	1	6
	RPS 2002	1	< 1			3			4		
Toutle River	RSW 0201	4	< 1	<1	< 1	2	1	2	2	2	3
Walla Walla River	RSE 0501	4	2	<1	4	6	4	8	8	7	10
Wenatchee River	RNC 0202	3	< 1	<1	< 1	2	2	3	3	3	4
White River	RPS 0801	2	< 1	<1	< 1	3	2	3	3	3	4
Wishkah River	RCP 2001	6	< 1	<1	< 1	< 1	<1	< 1	1	1	1
Wynoochee River	RCP 0601	2	< 1	<1	< 1	< 1	<1	1	1	1	2
Yakima River	RSC 0201	2	< 1	<1	< 1	2	1	2	2	2	3
	RSE 0201	2	< 1	<1	< 1	4	3	4	4	4	5
Network summary		184	< 1	<1	78	2.4	<1	17	3.8	1	95

[a] For averaging purposes, <1 is assumed to be equal to 0.5 pCi/liter. Averages less than 1 are recorded as <1.
[b] One analysis lost in laboratory, not included in average.
[c] Sample contained 4.2 g/liter of suspended matter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1962–June 1963	August 1964
July 1963–June 1964	February 1965
July 1964–June 1965	May 1966

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to gross beta-particle analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
HASL Fallout Network	July–December 1965	September 1966
HASL 80th Meridian Network	Calendar Year 1965	January 1967
National Air Sampling Network [1]	October–December 1966 and Annual Summary	April 1967
Plutonium in Airborne Particulates	October–December 1966	May 1967

[1] The National Air Sampling Network has discontinued the measurement of radioactivity on its air samples.

1. Radiation Surveillance Network April 1967

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Md., for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity by the station operators. These estimates are made after the decay of radon and thoran daughter products and prior to submission of the samples for laboratory analysis. When high level are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air and deposition by precipitation during April 1967. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2.

Gross beta radioactivity in air and precipitation continued to be near or below detectable levels. No indication of fresh fission products was found on any of the samples analyzed in April 1967.

REFERENCE

(*1*) RADIATION SURVEILLANCE NETWORK. Monthly tabulation of findings. National Center for Radiological Health, Public Health Service. Washington, D.C. 20201 (Distribution by official request).

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, April 1967

Station location		Number of samples		Air surveillance gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	30	1	0.29	0.05	0.17	Nov 66	30	< 6
Alaska:	Adak	30		.13	.00	.05	June 67	[c]	
	Anchorage	20	4	.18	.01	.06	Dec 66	6	< 1
	Attu Island	27		.10	.00	.05	July 67	[c]	
	Fairbanks	[b]					Jan 67	[c]	
	Juneau	16	3	.09	.00	.04	Apr 67	78	<16
	Kodiak	2		.05	.03	.04	May 67	[c]	
	Nome	[b]					Sept 66	[c]	
	Pt. Barrow	30		.12	.01	.07	Aug 67	[c]	
	St. Paul Island	[b]					Oct 66	[c]	
Ariz:	Phoenix	22		.59	.08	.21	Apr 67	[c]	
Ark:	Little Rock	28	7	.25	.03	.13	Dec 66	215	<43
Calif:	Berkeley	20	10	.15	.03	.08	May 67	132	<26
	Los Angeles	20	8	.14	.04	.07	Sept 66	85	<17
C.Z:	Ancon	16		.05	.02	.03	May 67	[c]	
Colo:	Denver	30	5	.30	.08	.17	May 67	89	<18
Conn:	Hartford	29	11	.26	.00	.14	Apr 67	95	<19
Del:	Dover	20		.23	.02	.14	Nov 66	[c]	
D.C:	Washington	30	7	.23	.01	.13	Aug 67	28	< 6
Fla:	Jacksonville	29	2	.31	.05	.16	Dec 66	16	< 3
	Miami	29	1	.30	.11	.20	Apr 67	10	< 2
Ga:	Atlanta	30		.35	.06	.19	Oct 66	[c]	
Guam:	Agana	29		.14	.00	.04	Nov 66	[c]	
Hawaii:	Honolulu	30	1	.29	.02	.08	July 67	35	< 7
Idaho:	Boise	28	10	.30	.04	.11	July 67	35	< 7
Ill:	Springfield	30	8	.49	.03	.14	Aug 67	73	<15
Ind:	Indianapolis	30	11	.30	.03	.15	Oct 66	90	<18
Iowa:	Iowa City	29	11	.23	.03	.12	May 67	122	<25
Kans:	Topeka	30	10	.31	.02	.14	Dec 66	161	<32
Ky:	Frankfort	28	6	.29	.03	.17	Aug 67	44	< 9
La:	New Orleans	30	2	.34	.06	.17	Aug 67	78	<16
Maine:	Augusta	30	11	.28	.02	.15	Sept 66	128	<26
	Presque Isle	6		.15	.09	.12	May 67	[c]	
Md:	Baltimore	20	3	.28	.02	.17	Apr 67	15	< 3
	Rockville	16		.21	.02	.13	July 67	[c]	
Mass:	Lawrence	30	10	.29	.03	.16	Nov 66	132	<26
	Winchester	18	9	.26	.02	.15	June 67	117	<23
Mich:	Lansing	30	10	.22	.01	.13	July 67	54	<11
Minn:	Minneapolis	19	7	.20	.03	.10	Nov 66	60	<12
Miss:	Jackson	29	3	.26	.01	.11	Sept 66	47	< 9
Mo:	Jefferson City	30	12	.33	.02	.11	Oct 66	91	<18
Mont:	Helena	30	7	.35	.00	.12	June 67	59	<12
Nebr:	Lincoln	13	8	.48	.01	.11	Oct 66	50	<10
Nev:	Las Vegas	27		.46	.08	.18	Jan 67	[c]	
N.H:	Concord	19		.26	.02	.15	Aug 67	[c]	
N.J:	Trenton	30	4	.25	.00	.12	Sept 66	16	< 3
N. Mex:	Santa Fe	30	1	.27	.04	.11	June 67	1	< 1
N.Y:	Albany	20	9	.24	.00	.12	Oct 66	88	<18
	Buffalo	21		.20	.02	.11	May 67	[c]	
	New York City	25		.29	.01	.13	June 67	[c]	
N.C:	Gastonia	29	6	.37	.03	.19	May 67	42	< 9
N.Dak:	Bismarck	30	9	.30	.02	.11	Aug 67	55	<11
Ohio:	Cincinnati	18		.27	.02	.14	Nov 66	[c]	
	Columbus	30	9	.39	.01	.19	Sept 66	80	<16
	Painesville	29	12	.29	.01	.14	Apr 67	72	<15
Okla:	Oklahoma City	29	9	.21	.02	.09	July 67	167	<33
	Ponca City	22	7	.12	.01	.05	Apr 67	56	<11
Ore:	Portland	28	14	.15	.02	.07	Oct 66	71	<14
Pa:	Harrisburg	28	1	.20	.01	.11	Oct 66	21	< 4
P.R:	San Juan	24	2	.33	.07	.16	Sept 66	40	< 8
R.I:	Providence	28	10	.27	.01	.13	July 67	107	<21
S.C:	Columbia	23	4	.28	.06	.15	June 67	58	<12
S.Dak:	Pierre	30	6	.35	.01	.12	Apr 67	29	< 8
Tenn:	Nashville	28	11	.24	.03	.13	July 67	73	<15
Tex:	Austin	30	5	.40	.05	.12	Nov 66	93	<19
	El Paso	28	1	.20	.04	.11	Aug 67	1	< 1
Utah:	Salt Lake City	30	11	.37	.11	.23	Sept 66	54	<11
Vt:	Barre	29	13	.31	.00	.13	Dec 66	76	<15
Va:	Richmond	30	6	.28	.02	.14	Dec 66	36	< 7
Wash:	Seattle	29	11	.13	.02	.07	Dec 66	62	<13
	Spokane	29	4	.22	.02	.10	Nov 66	13	< 3
W.Va:	Charleston	30	11	.32	.02	.13	June 67	86	<17
Wis:	Madison	29	13	.19	.00	.10	Dec 66	68	<15
Wyo:	Cheyenne	30	6	.31	.05	.13	Jan 67	64	<13
Network summary		1,835	393	.59	.00	.12		67	<14

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
[b] No report received.
[c] No precipitation sample collected.

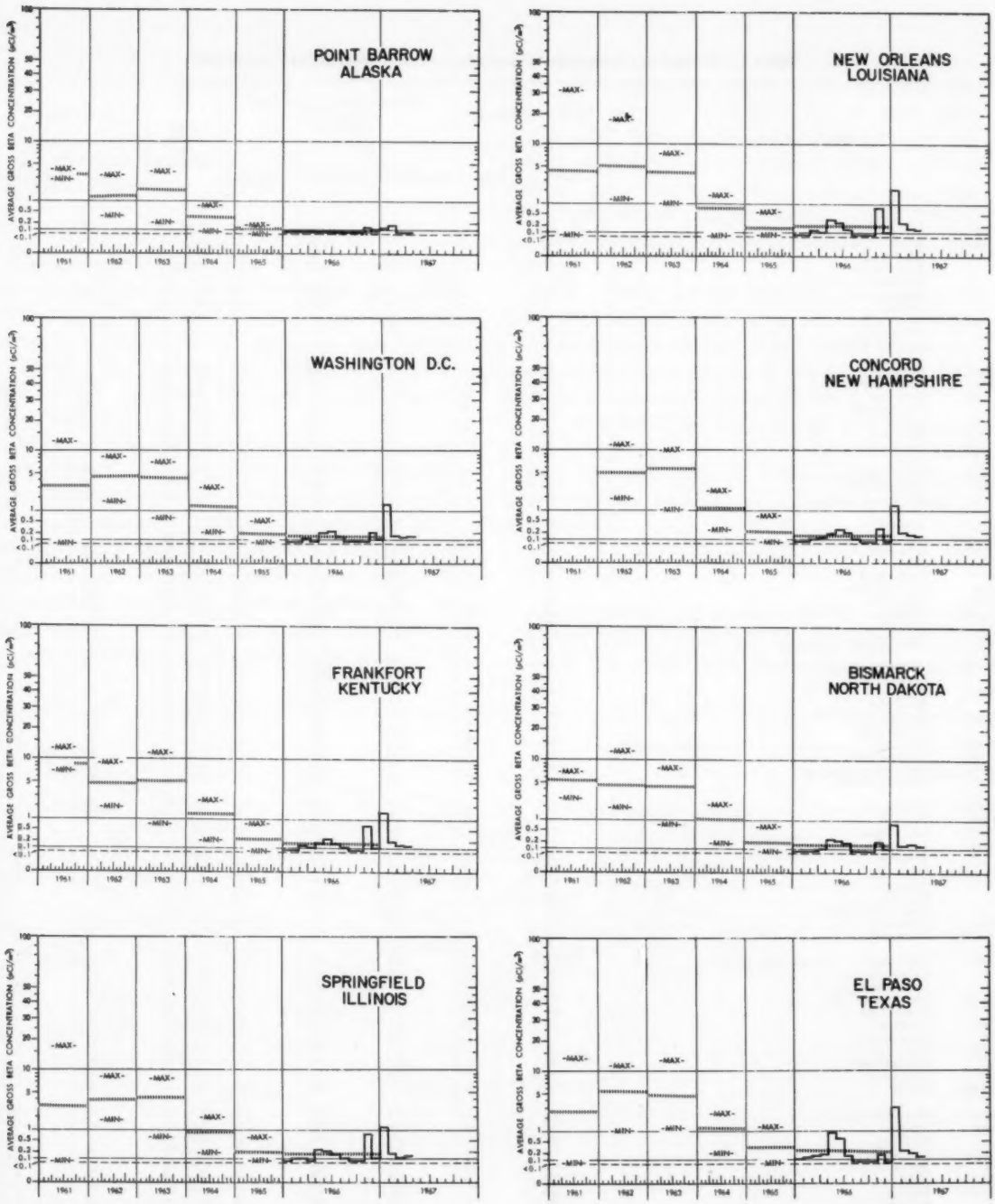

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Surveillance Network, 1960–April 1967

2. Canadian Air and Precipitation Monitoring Program, April 1967 [1]

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for April 1967 are presented in table 2.

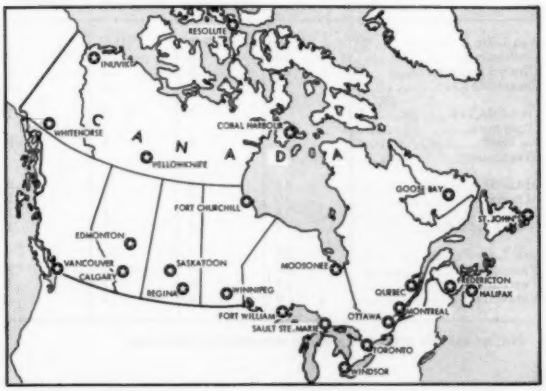

Figure 3. Canadian air and precipitation sampling stations

[1] Prepared from information and data in the May 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, April 1967

Station	Number of samples	Air surveillance radioactivity (pCi/m³)			Precipitation measurement	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	30	0.3	0.1	0.2	57	1.5
Coral Harbour	28	.2	.0	.1	50	0.5
Edmonton	30	.2	.0	.2	63	.4
Ft. Churchill	30	.3	.1	.1	69	.4
Ft. William	30	.3	.0	.2	38	3.2
Fredericton	30	.2	.0	.1	55	1.2
Goose Bay	30	.3	.1	.2	52	1.3
Halifax	30	.3	.0	.2	31	2.0
Inuvik	30	.2	.0	.1	29	.3
Montreal	30	.4	.0	.2	41	2.9
Moosonee	30	.3	.0	.2	20	1.0
Ottawa	30	.3	.0	.2	48	3.2
Quebec	30	.2	.1	.1	46	2.4
Regina	30	.3	.0	.1	88	.7
Resolute	30	.2	.1	.1	NS	NS
St. John's, Nfld.	30	.3	.0	.1	23	2.5
Saskatoon	30	.3	.0	.1	100	.4
Saulte Ste Marie	30	.3	.0	.2	NS	NS
Toronto	29	.4	.0	.2	39	2.6
Vancouver	30	.2	.0	.1	37	2.1
Whitehorse	30	.2	.0	.1	23	.5
Windsor	30	.3	.0	.2	32	2.7
Winnipeg	30	.3	.0	.2	27	2.0
Yellowknife	30	.2	.0	.1	108	.2
Network summary	-------	0.4	0.0	0.2	49	1.5

NS, no sample

REFERENCES

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*3*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*4*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*5*) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*6*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

3. Mexican Air Monitoring Program April 1967

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Figure 4. Fallout network sampling stations in Mexico

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days week at the rate of 1,000-cubic meters per day using high-volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, is has been found that a minimum of eight samples per month were needed to get a reliable average radioactivity at each station (*7*).

The maximum, minimum, and average fission product beta-particle concentrations in surface air during April 1967 are presented in table 4.

Table 4. Mexican gross beta radioactivity of airborne particulates, April 1967

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	18	0.6	0.2	0.3
Chihuahua	15	.6	.1	.2
Ciudad Juárez	11	.3	.1	.2
Ensenada	7	.2	.1	.1
Guadalajara	9	.1	< .1	.1
Guaymas	NS			
La Paz	10	.4	< .1	.2
Matamoros	NS			
Mazatlán	14	.4	.1	.2
Mérida	10	.3	.1	.1
México, D.F.	13	.1	.1	.1
Nuevo Laredo	7	.2	.1	.1
San Luis Potosí	NS			
Tampico	13	.3	< .1	.1
Torreón	17	.3	.1	.1
Veracruz	9	.2	.1	.1

NS, no sample collected, station temporarily shut down.

REFERENCE

(*7*) VASQUEZ, M., and R. M. DE NULMAN. Estudios sobre la Radioactividad Ambiental en la República Mexicana, 1963–1965. Comisión Nacional de Energía Nuclear. Dirección General de Seguridad Radiológica (en pressa 1966).

4. Pan American Air Sampling Program April 1967

Pan American Health Organization and
U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling sites are shown in figure 5.

The April 1967 air monitoring results from the participating countries are given in table 4.

Table 4. Gross beta radioactivity in surface air, PAHO, April 1967

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	20	0.07	0.02	0.04
Bolivia: La Paz	NS			
Chile: Santiago	28	.05	.02	.03
Colombia: Bogota	20	.02	.00	.01
Ecuador: Guayaquil	22	.03	.00	.02
Jamaica: Kingston	NS			
Peru: Lima	20	.06	.01	.03
Venezuela: Caracas	15	.05	.01	.03
West Indies: Trinidad	18	.07	.01	.05
Pan American summary	143	0.07	0.00	0.02

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no report received.

Figure 5. Pan American Air Sampling Program stations

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring in the vicinity of nuclear facilities.

Iodine-131 in Bovine Thyroids, January-March 1967

National Center for Radiological Health
Public Health Service

The National Center for Radiological Health established a Bovine Thyroid Network in October 1964 (*1*). Specimens are collected by the Meat Inspection Division, U.S. Department of Agriculture, and analyzed by gamma-ray spectroscopy for iodine–131 content at the Northeastern Radiological Health Laboratory, Winchester, Mass.

The network consists of collection areas (counties shaded in figure 1) located so as to cover, as nearly as possible, areas near major nuclear reactors, spent-fuel reprocessing plants, and nuclear test sites. Details of sampling and analysis have been published earlier (*1*). For this report, the collection areas sampled during January through March 1967 were grouped on a broad geographical basis as shown in figure 1.

The results for January through March 1967 appear in table 1 and are listed chronologically within the geographical groupings noted in figure 1; table 2 defines the State-County relationships. The influx of fallout iodine–131 following the mainland Chinese test of December 27, 1966, was observed throughout January 1967, declining to non-detectable levels by mid February 1967. Values greater than 500 pCi/g for individual specimens were observed in several of the geographical groupings sampled during the peak periods in January. Peak concentrations in individual bovine thyroids ranged from about 600 to 3,260 pCi/g in those areas that were sampled and where elevated thyroid levels were observed (grouping 1, particularly the central California counties; grouping 2; grouping 3; grouping 4; grouping 6).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1966	January 1967
July–December 1965	April 1967

REFERENCE

(*1*) BARATTA, E. J., E. R. WILLIAMS, and G. MURRAY. Iodine–131 in bovine thyroids, October–December 1964. Radiol Health Data 6:569–574 (October 1965).

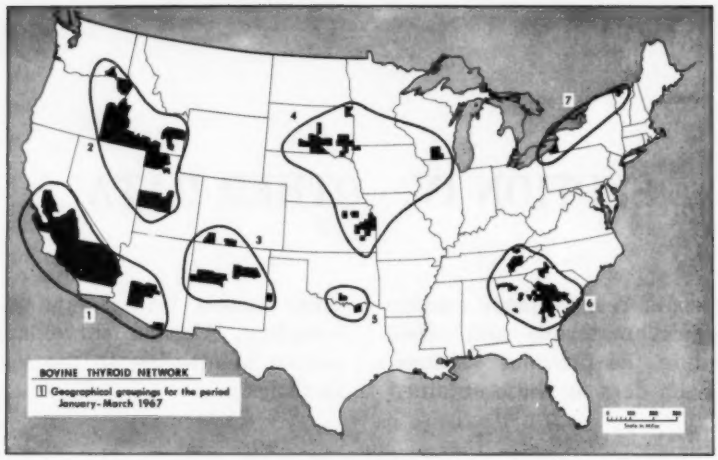

Figure 1. Counties sampled in bovine thyroid network, January–March 1967

Table 1. Iodine-131 in bovine thyroids, January–March 1967

Geographical grouping [a]	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
1 Arizona and California	1/3	Merced	2	5	ND	9
		Riverside	5	1	ND	4
		Stanislaus	2	ND		
	1/4	Monterey	2	5	ND	9
		San Bernardino	2	3	2	4
	1/5	Maricopa	2	ND		
		Orange	2	6	5	7
	1/9	San Joaquin	1	34		
		Stanislaus	2	28	26	30
	1/10	Monterey	2	367	249	485
		Riverside	5	24	ND	117
		San Joaquin	1	10		
	1/13	Maricopa	2	9	9	9
	1/16	Merced	2	593	188	997
	1/18	Kings	1	ND		
		San Bernardino	7	11	ND	34
		San Joaquin	2	18	3	32
	1/19	Los Angeles	1	24		
	1/20	Maricopa	2	ND		
	1/23	Merced	2	520	10	1,030
		Monterey	4	124	9	454
		Stanislaus	1	3,260		
		Tulare	1	7		
	1/24	San Bernardino	5	6	ND	25
	1/25	San Joaquin	2	58	11	104
		Santa Cruz	2	317	4	629
	1/26	Santa Cruz	2	1	ND	2
		San Bernardino	7	ND		
	1/30	Merced	2	13	ND	25
		Monterey	2	49	ND	98
		Stanislaus	2	47	ND	94
	1/31	San Joaquin	2	2	ND	3
		Stanislaus	2	68	2	133
	2/1	San Bernardino	2	ND		
	2/2	Santa Cruz	2	32	31	33
	2/3	Los Angeles	5	< 1	ND	2
	2/6	Fresno	1	ND		
		Merced	4	159	2	313
		San Bernardino	5	ND		
		Stanislaus	3	337	80	688
	2/7	Los Angeles	1	ND		
		Monterey	2	ND		
		San Bernardino	1	ND		
		San Joaquin	2	3	ND	5
	2/10	Maricopa	2	ND		
		Orange	2	1	ND	2
	2/13	Merced	2	9	ND	17
		Monterey	2	2	ND	3
		Stanislaus	2	88	ND	175
	2/14	San Joaquin	2	9	ND	18
		Stanislaus	2	3	ND	5

See footnotes at end of table.

Table 1. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping [a]	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
1 Continued	2/15	Santa Cruz	2	ND		
	2/16	San Bernardino	5	< 1	ND	2
	2/17	Kings	2	ND		
		Los Angeles	2	ND		
	2/20	Merced	2	150	20	279
		Monterey	2	4	ND	7
		Stanislaus	2	ND		
	2/21	San Bernardino	5	1	ND	3
		San Joaquin	2	3	ND	5
		Stanislaus	2	65	43	87
	2/23	Los Angeles	2	1	ND	2
	2/24	Maricopa	2	ND		
		Orange	2	4	ND	7
		Tulare	2	ND		
	2/27	Merced	4	2	ND	7
		Monterey	2	64	ND	128
		San Bernardino	2	ND		
	2/28	San Bernardino	4	ND		
		San Joaquin	2	1	ND	2
		Stanislaus	2	5	ND	9
	3/1	San Bernardino	1	ND		
	3/3	Maricopa	2	ND		
		Kings	2	2	2	2
	3/6	Fresno	2	3	ND	5
		Merced	2	ND		
		Orange	2	ND		
		Stanislaus	2	ND		
	3/7	San Bernardino	5	< 1	ND	2
		San Joaquin	2	6	ND	12
		Stanislaus	2	11	10	12
	3/9	Merced	1	ND		
		Stanislaus	1	ND		
	3/10	Maricopa	2	ND		
		Los Angeles	4	ND		
	3/13	Fresno	2	ND		
		Merced	2	ND		
		Monterey	2	32	ND	64
	3/14	Monterey	2	ND		
		Stanislaus	2	ND		
	3/15	Kern	5	48	26	78
	3/17	Maricopa	2	6	ND	11
		Ventura	2	ND		
	3/20	Merced	2	2	ND	3
		Monterey	2	ND		
		Stanislaus	2	ND		
	3/21	San Joaquin	4	ND		
		Stanislaus	2	ND		
	3/22	Maricopa	2	ND		
		San Bernardino	3	ND		
	3/23	San Bernardino	1	ND		
	3/27	Monterey	2	ND		
		Stanislaus	4	6	ND	15
	3/28	San Bernardino	1	ND		
		San Joaquin	2	7	ND	13
		Stanislaus	2	5	4	5
	3/29	San Bernardino	1	ND		
	3/30	Los Angeles	2	ND		
		Orange	2	1	ND	2
	3/31	Tulare	2	ND		
2 Idaho, Oregon, Utah, and Washington	1/6	Bannock	5	54	ND	97
		Canyon	5	14	11	18
	1/11	Ada	5	89	2	185
		Millard	3	326	286	367
	1/12	Sevier	2	19	17	20
	1/18	Sanpete	5	14	6	23
	1/20	Canyon	2	28	25	30
		Gem	6	28	4	48
		Payette	2	562	313	810
	1/25	Cassia	5	2	2	3
	1/26	Sevier	5	44	17	97
	1/30	Walla Walla	7	254	6	1,004
	1/31	Sanpete	5	5	3	6
	2/1	Bingham	5	ND		
	2/7	Bonneville	5	ND		
	2/8	Canyon	2	12	5	19
		Gem	3	132	5	382
	2/14	Davis	5	2	ND	5
		Owyhee	1	ND		
	2/15	Owyhee	1	ND		
	2/18	Ada	2	ND		
		Owyhee	1	ND		
	2/21	Ada	2	ND		
		Gem	2	2	ND	3
	2/22	Owyhee	1	40		
	2/24	Malheur	1	ND		
	3/2	Walla Walla	10	44	ND	140

See footnotes at end of table.

Table 1. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping [a]	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
2 Continued	3/7	Ada	1	ND		
		Owyhee	1	ND		
	3/10	Ada	3	ND		
	3/14	Walla Walla	1	ND		
	3/17	Jerome	5	ND		
		Malheur	9	< 1	ND	2
	3/21	Box Elder	5	1	ND	3
	3/23	Canyon	10	< 1	ND	2
	3/28	Cassia	5	1	ND	5
	3/31	Canyon	1	ND		
		Payette	1	ND		
		Twin Falls	1	ND		
		Wallowa	1	3		
		Washington	1	ND		
3 Colorado, New Mexico, and Western Texas	1/2	Conejos	8	2	ND	8
	1/3	Bernalillo	8	1	ND	2
	1/9	Valencia	8	13	4	17
	1/10	San Miguel	8	457	118	939
	1/16	Bernalillo	8	9	3	24
	1/17	Bernalillo	8	3	2	5
	1/23	Bernalillo	8	247	24	496
	1/24	La Plata	8	10	5	19
	2/6	Bernalillo	2	ND		
	2/7	Bernalillo	6	ND		
	3/31	Bailey	2	ND		
4 Iowa, Kansas, South Dakota, and Wisconsin	1/5	Miner	5	12	2	19
		Turner	2	13	12	13
	1/6	Anderson	3	186	20	271
	1/10	Rock	5	4	ND	9
		Tripp	1	621		
	1/11	Hanson	1	24		
		Lake	1	130		
		Lyon (Iowa)	1	ND		
	1/13	Clay	2	52	45	59
		Dane	3	1	ND	3
	1/17	Mellette	10	178	31	607
	1/18	Franklin	1	64		
	1/20	Dane	2	6	6	6
	1/24	Lake	4	7	4	9
		Lyon (Iowa)	3	44	10	67
	1/25	Green	1	17		
		Johnson	2	23	20	25
		Rock	4	5	ND	14
	1/27	Green	2	ND		
		Rock	1	ND		
	1/31	Lake	5	15	5	29
	2/2	Lyman	1	127		
		Mellette	1	144		
		Osage	1	13		
	2/3	Lyon (Kansas)	2	3	2	4
		Rock	2	ND		
	2/6	Rock	8	ND		
	2/8	Yankton	7	6	3	10
	2/13	Dane	9	ND		
	2/17	Douglas	2	10	9	10
	2/20	Dane	1	ND		
		Rock	1	ND		
	2/21	Gregory	9	ND		
	2/22	Rock	8	ND		
	2/23	Leavenworth	3	ND		
	2/27	Dane	2	ND		
		Rock	1	ND		
	3/1	Brule	4	1	ND	4
		Johnson	1	4		
		Lyon (Iowa)	6	6	ND	27
		Woodson	4	28	3	40
	3/3	Rock	4	ND		
	3/4	Gregory	1	ND		
		Roberts	1	ND		
	3/6	Lake	3	1	ND	2
		Turner	2	ND		
	3/8	Minnehaha	5	9	6	12
	3/10	Miami	1	9		
	3/13	Lyman	4	5	2	8
		Mellette	2	6	5	7
	3/15	Franklin	1	3		
		McCook	3	6	3	10
	3/17	Lyon (Kansas)	2	ND		
		Pottawatomie	1	3		
	3/21	Aurora	1	ND		
		Hyde	1	ND		
	3/22	Rock	7	ND		
	3/24	Rock	3	ND		
		Wyandotte	2	1	ND	2
	3/28	Gregory	1	ND		
		Miner	2	ND		
		Roberts	1	ND		
	3/29	Douglas	3	3	ND	4

See footnotes at end of table.

Table 1. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping *	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
4 Continued	3/30	Rock	8	ND		
	3/31	Franklin	1	ND		
		Leavenworth	1	ND		
5 Oklahoma and Eastern Texas	3/22	Carter	1	6		
	3/27	Fannin	1	ND		
6 Georgia, North Carolina, South Carolina and Tennessee	1/3	Jenkins	1	5		
		McCormick	1	4		
		Saluda	1	4		
		Spartanburg	1	4		
		Upson	1	ND		
		Warren	1	ND		
		Wilkes	3	5	4	5
	1/4	Knox	3	12	3	19
		Sevier	3	20	11	36
	1/9	Toombs	10	293	4	1,010
	1/10	Blount	3	810	172	1,655
		Monroe	2	861	676	1,045
	1/14	Knox	1	ND		
	1/16	Bamberg	1	8		
	1/17	Bamberg	9	42	2	146
		Blount	3	675	38	1,856
		Knox	2	412	35	788
	1/24	Barnwell	1	224		
		Blount	3	389	84	994
		Edgefield	1	4		
		Knox	2	493	38	947
		McDuffie	1	5		
		Saluda	2	572	424	719
	1/24	Cleveland	2	542	510	574
		Upson	2	413	132	693
		Warren	1	7		
	1/31	Blount	2	251	195	306
		Cleveland	1	22		
		Gordon	1	266		
		Knox	4	16	9	25
		Lexington	1	33		
		McCormick	1	287		
		Richmond	1	214		
		Saluda	2	95	85	105
		Screven	1	23		
		Upson	1	334		
		Warren	1	29		
	2/7	Abbeville	1	22		
		Blount	1	377		
		Bulloch	1	48		
		Burke	1	7		
		Greenwood	2	16	ND	32
		Knox	3	9	7	11
		Saluda	2	78	9	146
		Screven	1	311		
		Sevier	2	204	203	205
		Warren	1	127		
	2/14	Barnwell	1	25		
		Blount	1	11		
		Bulloch	1	40		
		Cleveland	2	34	27	40
		Greenwood	2	62	23	101
		Jefferson	1	7		
		Knox	1	ND		
		McCormick	1	81		
		McDuffie	1	33		
		Orangeburg	1	36		
		Sevier	1	6		
		Wilkes	1	26		
	2/21	Barnwell	1	25		
		Emanuel	1	3		
		Greenwood	1	31		
		Saluda	1	ND		
		Toombs	5	11	2	29
		Wilkes	1	2		
	2/22	Blount	2	30	29	30
		Sevier	4	10	4	20
	2/28	Burke	1	12		
		Chattooga	1	16		
		Claiborne	2	ND		
		Columbia	2	65	64	66
		Greenwood	1	19		
		Knox	1	13		
		Lexington	2	16	14	18
		Saluda	1	10		
		Sevier	1	ND		
		Wilkes	2	3	2	3
	3/7	Aiken	1	ND		
		Blount	3	3	3	3
		Columbia	1	ND		
		Greene	1	ND		
		Greenwood	1	ND		
		Saluda	2	2	ND	4

See footnotes at end of table.

Table 1. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping [a]	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
6 Continued		Screven	2	2	ND	3
		Sevier	2	ND		
		Warren	2	2	ND	3
	3/14	Walton	10	4	ND	11
	3/15	Blount	1	ND		
		Jefferson	1	2		
		Knox	3	3	ND	7
		Sevier	1	17		
	3/21	Blount	1	ND		
		Cherokee	4	1	ND	3
		Cleveland	2	1	ND	2
		Forsyth	2	ND		
		Knox	2	2	ND	3
		Loudon	2	4	3	4
		Newton	1	6		
		Walton	1	8		
	3/28	Bamberg	1	2		
		Dorchester	2	4	ND	7
		Greenwood	3	ND		
		Knox	3	ND		
		Pickens	3	5	4	6
		Saluda	1	ND		
	3/29	Sevier	1	2		
7 New York and Vermont	1/11	Chautauqua	10	3	ND	15
		Franklin	10		ND	3
	1/18	Chautauqua	10	2	ND	6
	1/24	Franklin	10	ND		
	1/26	Chautauqua	10	1	ND	5
	2/1	Chautauqua	10	1	ND	5
	2/8	Chautauqua	10	ND		
		Franklin	10	ND		
	2/20	Franklin	3	ND		
	2/21	Franklin	7	ND		
	2/23	Chautauqua	10	ND		
	3/8	Chautauqua	10	< 1	ND	2
		Franklin	10	ND		
	3/16	Chautauqua	10	ND		
	3/20	Franklin	10	ND		
	3/23	Chautauqua	10	ND		

[a] Geographical areas as designated in figure 1, encompassing those counties that were sampled in the States indicated.
ND, non-detectable: the two standard deviation counting error was greater than or equal to the concentration observed. For the counting system utilized and these very low concentrations the two standard deviation counting errors were generally 1–3 pCi/g thyroid.

Table 2. State-county relationships

State	County		State	County	
Arizona	Maricopa		New Mexico	Bernalillo	
	Santa Cruz			San Miguel	
California	Fresno	Riverside		Valencia	
	Kern	San Bernardino-	Oklahoma	Carter	
	Kings	San Joaquin	Oregon	Malheur	
	Los Angeles	Santa Cruz		Wallowa	
	Merced	Stanislaus	South Carolina	Abbeville	Greenwood
	Monterey	Tulare		Aiken	Lexington
	Orange	Ventura		Bamberg	McCormick
Colorado	Conejos			Barnwell	Orangeburg
	La Plata			Cherokee	Saluda
Georgia	Burke	McDuffie		Dorchester	Spartanburg
	Bulloch	Newton		Edgefield	
	Chattooga	Pickens	South Dakota	Aurora	Mellette
	Cherokee	Richmond		Brule	Miner
	Columbia	Screven		Gregory	Minnehaha
	Emanuel	Toombs		Hanson	Roberts
	Forsyth	Upson		Hyde	Tripp
	Gordon	Walton		Lake	Turner
	Greene	Warren		Lyman	Yankton
	Jenkins	Wilkes		McCook	
Idaho	Ada	Gem	Tennessee	Blount	Loudon
	Bannock	Jerome		Claiborne	Monroe
	Bingham	Owyhee		Jefferson	Sevier
	Bonneville	Payette		Knox	
	Canyon	Twin Falls	Texas	Bailey	
	Cassia	Washington		Fanin	
Iowa	Lyon		Utah	Box Elder	Sanpete
Kansas	Anderson	Lyon		Davis	Sevier
	Clay	Miami		Millard	
	Douglas	Osage	Vermont	Franklin	
	Franklin	Pattawatomie	Washington	Walla Walla	
	Johnson	Woodson	Wisconsin	Dane	
	Leavenworth	Wyandotte		Green	
North Carolina	Cleveland			Rock	
New York	Chautauqua				

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of the environmental radioactivity data follow for Atomics International, the Feed Materials Production Center, and the Oak Ridge Gaseous Diffusion Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International July–December 1966 [2]

North American Aviation, Inc.
Canoga Park, California

Atomics International, a Division of North American Aviation, Incorporated, has been engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants and for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, Calif., approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is in Ventura County in the Simi Hills approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International encourages total containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a check on the effectiveness of radiological safety procedures and of engineering safeguards incorporated into facility design.

The environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. In addition, continuous environmental air monitoring at the sites provides information concerning airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV–70 filter paper which is automatically changed at the end of

[2] Summarized from "Environmental Monitoring, Semiannual Report, July 1, 1966 to December 31, 1966 and Annual Report 1966," Atomics International, Division of North American Aviation, Inc.

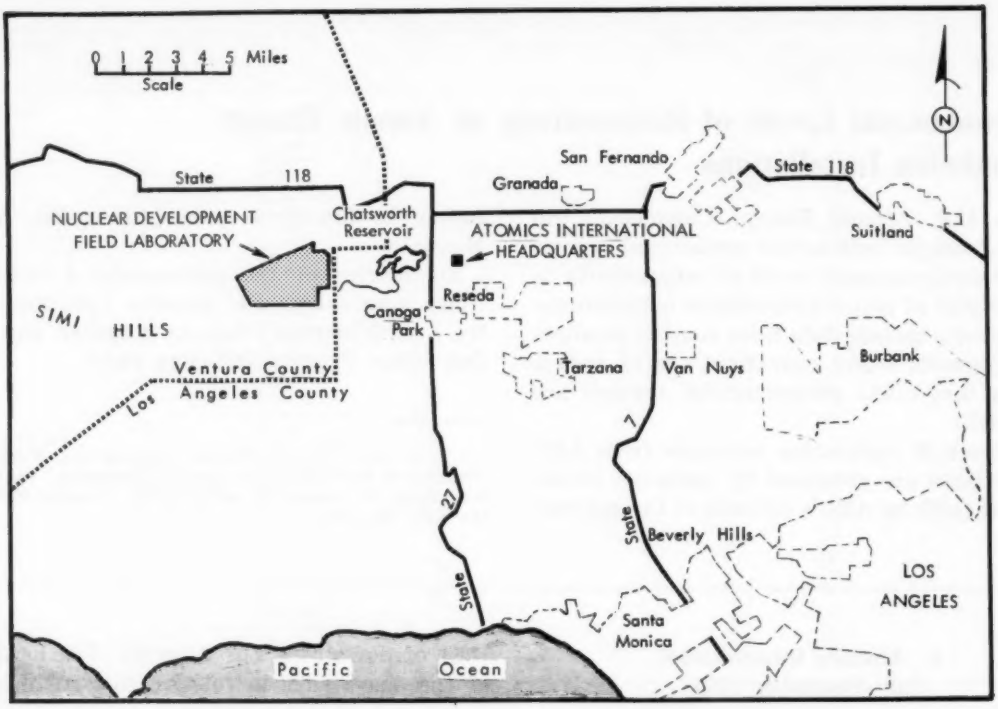

Figure 1. Atomics International facilities and vicinity

each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours. The volume of a typical daily environmental air sample is approximately 20-cubic meters. The average concentration of long-lived beta-gamma radioactivity on airborne particulates is presented in table 1 for the first and the last half of 1966.

Table 1. Beta-gamma radioactivity of airborne particulates, Atomics International, 1966

Location	January-June 1966		July-December 1966	
	Number of samples	Average concentration (pCi/m³)	Number of samples	Average concentration (pCi/m³)
Headquarters	360	0.14	346	0.21
NDFL	1,178	.16	1,027	.18

Water monitoring

Process water used at the NDFL is obtained from wells and stored in two 50,000-gallon tanks. Potable water is delivered to the site by a vendor and is not analyzed. Well water is sampled monthly from the supply line at two locations. The average well water radioactivity is presented in table 2.

Table 2. Well water radioactivity, NDFL site Atomics International, 1966

Type of radioactivity	January-June 1966		July-December 1966	
	Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Alpha	12	0.11	12	0.15
Beta-gamma	12	5.9	12	3.2

Water samples are also collected monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The average radioactivity for both surface and supply water samples is presented in table 3.

Table 3. Chatsworth Reservoir water radioactivity Atomics International, 1966

Sample	Type of radioactivity	January-June 1966		July-December 1966	
		Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	6	0.35	6	0.29
	Beta-gamma	6	6.6	6	5.2
Supply inlet	Alpha	6	.47	6	.35
	Beta-gamma	6	6.9	6	4.8

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 3.4 miles downstream from the south NAA Boundary. Samples, obtained and analyzed monthly, include stream-bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 4.

Table 4. Radioactivity in the Main Holding Reservoir[a] and Bell Creek, Atomics International, July–December 1966

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir Sta. 6[a] (pCi/liter)	5	0.07	5.3
Reservoir Sta. 12[a] (pCi/liter)	6	1.4	6.6
Bell Creek Mud (pCi/g)	3	.39	25
Bell Creek Vegetation (pCi/g ash)	3	1.13	108
Bell Creek Water (pCi/liter)	3	.75	1.3

[a] Locations not shown on figure 3.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 24 locations. Twelve sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 12 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top one-half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 5.

Table 5. Radioactivity in the soil Atomics International, 1966

Area	Type of radioactivity	January-June 1966		July-December 1966	
		Number of samples	Average concentration (pCi/g)	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	72	0.39	72	0.43
	Beta-gamma	72	31	70	28
Offsite	Alpha	24	.45	24	.43
	Beta-gamma	24	25	24	24

Vegetation samples obtained in the field are of the same plant type wherever possible, generally, sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 6.

Table 6. Radioactivity in vegetation Atomics International, 1966

Area	Type of radioactivity	January-June 1966		July-December 1966	
		Number of samples	Average concentration (pCi/g ash)	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	72	0.40	72	0.35
	Beta-gamma	72	176	72	162
Offsite	Alpha	24	.39	24	.35
	Beta-gamma	24	130	24	117

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Second half 1965	Septemer 1966
First half 1966	March 1967

2. Feed Materials Production Center July–December 1966 [3]

National Lead Company
Fernald, Ohio

The Feed Materials Production Center (FMPC) is operated by the National Lead Company of Ohio for the AEC. The location as related to populated areas is shown in figure 2. Cincinnati and Hamilton—the larger nearby communities—are situated 20 and 10 miles, respectively, from the Center. Operations at this project deal with the processing of high-grade uranium ores and ore concentrates to produce metallic uranium and with fabricating the metal into fuel elements.

During the many involved reactions and processes that lead to the reactor fuels, various liquid and airborne wastes are generated. These wastes contain varying quantities of uranium. Various in-plant methods are used to curtail their release into the environment surrounding the plant. Almost complete removal of the materials is accomplished by using dust collectors and waste treatment processes. In order to determine what concentrations reach the area surrounding the project an environmental survey program has been established which consists of water, soil, and air sampling of the environs and performing those analyses on the samples that are indicative of material released from the plants.

Onsite air samples are obtained from four permanent perimeter air sampling stations, located at the four corners of the production area, shown in figure 3. Samples from these perimeter stations are collected once each week and analyzed for uranium and total radioactivity. Offsite samples are collected by a mobile air sampling unit. The location at which samples are collected is determined by local meteorological conditions on the day of sampling. Approximately 20 percent of all samples are taken upwind of the FMPC plant. Replicate samples are taken at each sampling point and averaged to obtain a representative concentration for that location. Concentrations of uranium and total radioactivity of airborne particulates sampled at onsite and offsite locations are given in table 7.

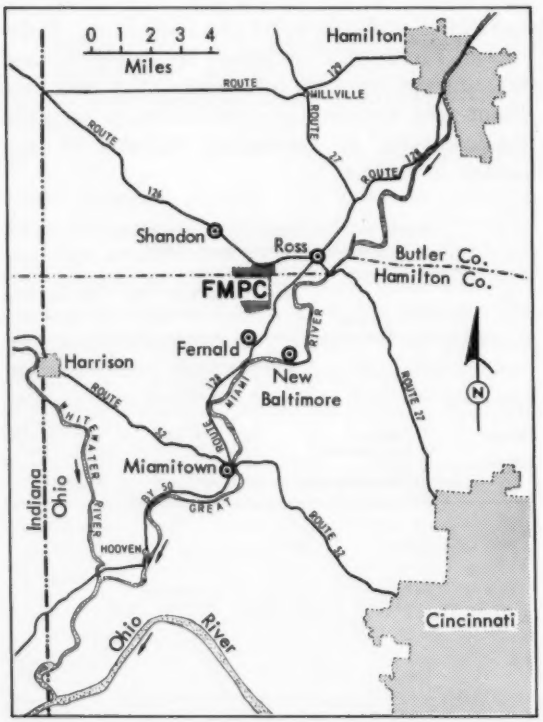

Figure 2. Area map of Feed Materials Production Center

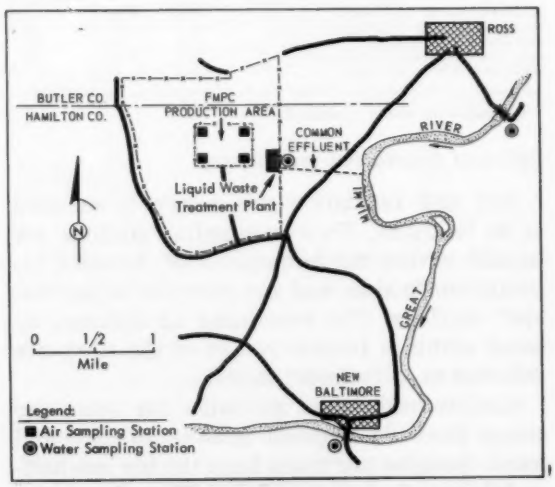

Figure 3. Air and water sampling stations, FMPC

[3] Summarized from "Feed Materials Production Center Environmental Monitoring Semi-Annual Report for the Second Half of 1966, Summary Report for 1966" (NLCO–992).

Table 7. Radioactivity levels of airborne particulates, Feed Materials Production Center, July–December 1966

Location	Number of samples	Uranium concentration (pCi/m³)[a]			Total radioactivity (pCi/m³)[b]		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Onsite:							
Southwest	28	0.7	<0.1	0.1	4.2	<0.1	0.5
Northwest	26	.2	< .1	< .1	1.1	< .1	.2
Northeast	28	1.0	< .1	.1	1.8	< .1	.3
Southeast	28	.5	< .1	.1	1.1	< .1	.2
All onsite samples	110	1.0	< .1	.1	4.2	< .1	.3
Offsite:							
0–2 miles from FMPC	22	.7	< .1	< .2	8.6	.1	1.3
2–4 miles from FMPC	35	.2	< .1	< .1	1.4	< .1	.3
4–8 miles from FMPC	19	.1	< .1	< .1	.4	< .1	.1
8–12 miles from FMPC	6	< .1	< .1	< .1	.2	< .1	< .1
All offsite samples	82	.7	< .1	.1	8.6	< .1	.5

[a] AEC radiation protection standard—2 pCi/m³.
[b] AEC radiation protection standard—100 pCi/m³.

Water monitoring

Each of the individual production plants on the project has collection sumps and treatment equipment to remove the uranium from the process waste water. The effluent from the plants is collected at a general sump for equalization and settling. The clear water from the sump is pumped to the river. The solid portion is pumped to a chemical waste pit for further settling. The flow, which is decanted to the clear-well portion of the pit, is virtually free of solids and radioactivity. The effluent from the sump and clear well is combined with waste water from the FMPC water treatment plant, sanitary sewage treatment plant, and storm sewerage system and discharged via a common effluent outfall into the Great Miami River. A weir-type water sampler collects samples of the combined effluent stream, which are removed and analyzed daily. These results are utilized with measurements of river flow in calculating the radioactive contaminant concentrations added to the river. Weekly spot samples are also obtained upstream and downstream from the common FMPC effluent at locations shown in figure 3. The results of the FMPC water monitoring program for July-December 1966 are summarized in table 8.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	October 1966
January–June 1966	April 1967

Table 8. Radioactivity in the Great Miami River, Feed Materials Production Center, July–December 1966

Location	Number of samples	Uranium concentration (pCi/liter)[a]			Total radioactivity (pCi/liter)[b]		
		High	Low	Average	High	Low	Average
Sewer outfall	181	110	<10	2	220	<10	<10
Upstream from outfall	24	40	<10	10	100	<10	30
Downstream from outfall	29	60	<10	13	140	<10	40

[a] AEC radiation protection standard—20,000 pCi/liter.
[b] AEC radiation protection standard—3,000 pCi/liter.

3. Oak Ridge Area
July–December 1966 [4]

Union Carbide, Nuclear Company
Oak Ridge, Tennessee

The Oak Ridge Area is a complex made up primarily of the Y–12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in the Oak Ridge area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ability to fix radioactive materials by an ion exchange mechanism. Liquid wastes which contain long-lived fission products are confined in storage tanks or are released to trenches located in the Conasauga shale formation. Low-level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of East Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations which encircle the plant areas (figure 4) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of eight stations encircling the Oak Ridge area at distances of from 12 to 75 miles (figure 5). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur.

Sampling for radioactive particulates is carried out by passing air continuously through a filter paper. Average concentrations are presented in tables 9 and 10. Airborne radioactive iodine is monitored in the immediate environment of the plant areas by passing air through a cartridge containing activated charcoal.

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[4] Summarized from "Environmental Levels of Radioactivity for the Oak Ridge Area" (Report Period, July–December 1966). Health Physics and Safety Section, Health Physics Division, Oak Ridge National Laboratory.

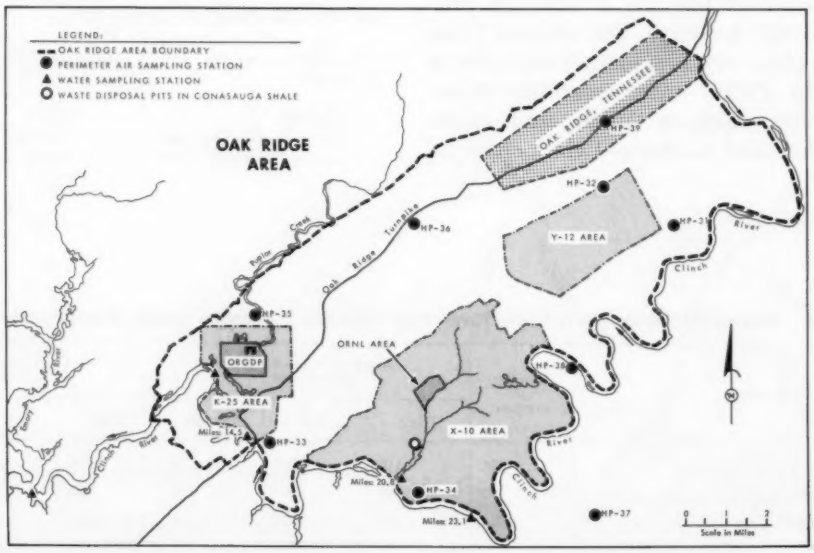

Figure 4. Oak Ridge area environmental sampling locations

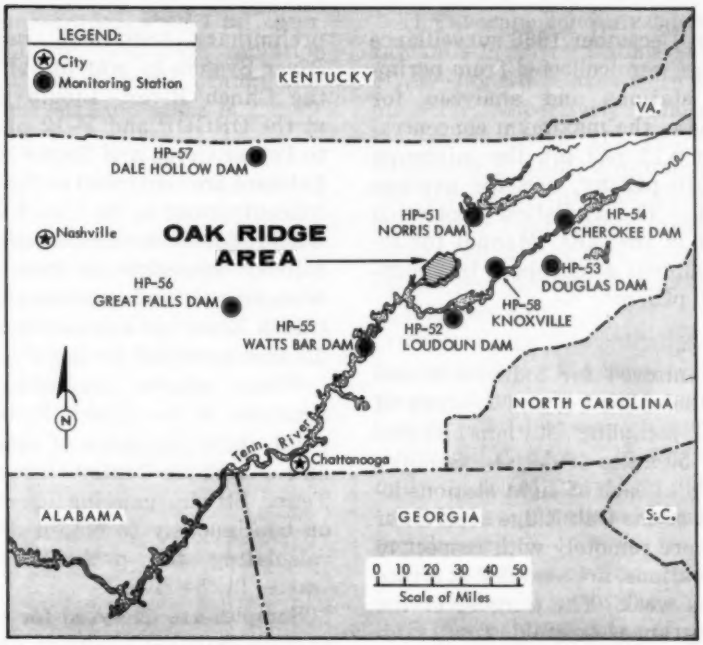

Figure 5. Remote air monitoring stations, Oak Ridge area

Table 9. Long-lived gross beta radioactivity of particulates in air, Oak Ridge area, July–December 1966

Perimeter stations				Remote stations			
Station number (figure 1)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard *	Station number (figure 2)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard *
HP-31	26	0.09	0.09	HP-51	26	0.11	0.11
HP-32	26	.11	.11	HP-52	25	.10	.10
HP-33	26	.08	.08	HP-53	26	.10	.10
HP-34	26	.08	.08	HP-54	26	.09	.09
HP-35	26	.09	.09	HP-55	26	.09	.09
HP-36	182	.14	.14	HP-56	26	.12	.12
HP-37	26	.08	.08	HP-57	26	.09	.09
HP-38	26	.10	.10	HP-58	24	.11	.11
HP-39	26	.11	.11				
Average		0.10	0.10	Average		0.10	0.10

* The applicable AEC Radiation Protection Standard is 100 pCi/m³.

Table 10. Long-lived gross alpha radioactivity of particulates in air, Oak Riage area, July–December 1966

Perimeter stations				Remote stations			
Station number (figure 1)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard *	Station number (figure 2)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard *
HP-31	26	0.005	0.25	HP-51	26	0.004	0.20
HP-32	26	.007	.35	HP-52	25	.004	.20
HP-33	26	.005	.25	HP-53	26	.003	.15
HP-34	26	.004	.20	HP-54	26	.003	.15
HP-35	26	.008	.40	HP-55	26	.003	.15
HP-36	182	.013	.65	HP-56	26	.003	.15
HP-37	26	.004	.20	HP-57	26	.003	.15
HP-38	26	.003	.15	HP-58	24	.004	.20
HP-39	26	.006	.30				
Average		0.006	0.30	Average		0.003	0.15

* The applicable AEC Radiation Protection Standard for natural uranium in air is 2 pCi/m³.

During the July–December 1966 surveillance period, 206 samples were collected from perimeter monitoring stations and analyzed for iodine–131. Of these, the maximum concentration detected was 0.12 pCi/m³, the minimum was less than 0.010 pCi/m³, and the average was 0.012 pCi/m³. The radiation protection standard specified in the AEC Manual for iodine–131 in the ambient atmosphere in uncontrolled areas is 100 pCi/m³.

Milk monitoring

Raw milk is monitored for iodine–131 and strontium–90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of ORNL. Samples are collected weekly at each of eight stations located on the fringe of the Oak Ridge area. Four stations, located more remotely with respect to the Oak Ridge operations, are sampled at a rate of one station each week. The purpose of the milk sampling program is twofold: first, samples collected in the immediate vicinity of the Oak Ridge area provide data by which one may evaluate possible exposure to the neighboring population resulting from waste releases from Oak Ridge operations; second, samples collected at the more remote stations provide background data which are essential in establishing the proper index for the evaluation of data obtained from local samples. The concentrations of iodine–131 and strontium–90 detected in raw milk samples during the period are given in table 11.

Water monitoring

Large volume, low-level liquid wastes originating at ORNL are discharged, after some preliminary treatment, into the Tennessee River System by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and Y–12 plant are discharged to Poplar Creek and thence to the Clinch River. Releases are controlled so that resulting average concentrations in the Clinch River comply with AEC radiation protection standards. The radioactivity concentration from White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tenn. Stream gauging operations are carried on continuously to obtain dilution factors for calculating the probable concentrations of wastes in the river.

Samples are analyzed for the long-lived beta particle emitters, uranium, and the transuranic alpha-particle emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold up time in the waste effluent system are such that short-lived radionuclides are normally not present. The average concentrations of major radionuclides in the Clinch River are given in table 12 for the period from July through December 1966.

Two quarterly composite water samples from the Clinch River were analyzed for uranium during this period. For both samples, the ura-

Table 11. Radionuclides in raw milk, Oak Ridge area July–December 1966

Radionuclide and location	Concentration, pCi/liter		
	Maximum	Minimum [a]	Average
Iodine-131			
Immediate environs	114	<10	8
Remote environs	15	<10	6
Strontium-90			
Immediate environs	53	7	27
Remote environs	40	14	24

[a] The minimum detectable concentrations of iodine-131 and strontium-90 in milk are 10 pCi/liter and 2 pCi/liter, respectively. In averaging, one-half of the minimum detectable concentration was used for all samples showing an activity less than this concentration.

Table 12. Concentrations of major radionuclides in the Clinch River, July–December 1966

Radionuclide	Average concentration (pCi/liter)		
	Location on Clinch River [a]		
	Mile 23.1 [b] (Upstream)	Mile 20.8 [c] (Outfall)	Mile 4.5 (Downstream)
Strontium-90	0.5	0.6	1.3
Cerium-144	0.2	<0.1	0.3
Cesium-137	ND	0.2	1.9
Ruthenium-106	0.1	4.3	2.0
Cobalt-60	ND	0.5	1.3
Zirconium-niobium-95	ND	0.1	ND
Gross beta	0.8	14	6.8

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River. See figure 1.

[b] Sampling station moved from Clinch River mile (CRM) 41.5 to Melton Hill Dam CRM 23.1 about January 1, 1966.

[c] The concentrations at mile 20.8 are not measured directly but the values are calculated based on the levels of waste released and the dilution afforded by the river.

ND, non-detectable.

nium concentrations were less than 1 pCi/liter, the level of detectability. The AEC radiation protection standard for natural uranium in water released to unrestricted areas is 2×10^4 pCi/liter.

Gamma measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above the ground. The results are shown in table 13 in terms of mR/hr.

Table 13. External gamma radiation levels, Oak Ridge area, July–December 1966 [a]

Location	Average dose rate (mR/hr)
Solway Gate	0.012
Y–12, East Portal	0.011
Newcomb Road	0.012
Gallaher Gate	0.011
White Wing Gate	0.012
Five locations	0.012

[a] The background in the Oak Ridge area determined in 1943 was approximately 0.012 mR/hr.

Discussion of data

The average air contamination levels for gross beta radioactivity, as shown by the continuous air monitoring filter data, for both the immediate and remote environs of the plants (figures 4 and 5) were 0.10 percent of the AEC radiation protection standard for populations in the neighborhood of a controlled area. These levels are approximately the same as those for the first half of 1966.

The average air contamination levels for gross alpha radioactivity (as shown by the continuous air monitoring filter data) for the immediate and remote environs of the plants were 0.30 percent and 0.15 percent, respectively, of the AEC radiation protection standard for natural uranium for application to populations in the neighborhood of a controlled area.

The average concentration of iodine–131 in air in the immediate environs of the plants was 0.012 pCi/m^3. This is approximately 0.012 percent of the AEC radiation standard for populations in the neighborhood of a controlled area.

The average concentrations of iodine–131 in raw milk in the immediate and remote environs of the Oak Ridge area were 8 pCi/liter and 5.9 pCi/liter, respectively. The maximum concentration observed, 114 pCi/liter, occurred on November 9, 1966, approximately 4 days after the arrival in the Oak Ridge area of fallout containing fresh fission products. The average values fall within FRC Range I if the average intake per individual is assumed to be 1 liter of milk per day.

The average concentrations of strontium -90 in raw milk in the immediate and remote environs of the controlled area were 27 pCi/liter and 24 pCi/liter, respectively. These levels fall within FRC Range II for transient rates of daily intake of strontium–90 for application to the average of suitable samples of an exposed population.

The calculated average concentration of gross beta radioactivity in the Clinch River at mile 20.8 (the point of entry of most of the wastes) and the measured average concentration at mile 4.5 (near Kingston, Tenn.) were 14 pCi/liter and 6.8 pCi/liter, respectively. These values are 0.63 percent and 0.45 percent of the weighted average AEC radiation protection standards. The average concentration of transuranic alpha particle emitters in the Clinch River at mile 20.8 was 0.10 pCi/liter which is approximately 0.005 percent of the weighted average AEC radiation protection standard.

The average activity of natural uranium materials in the Clinch River, reflecting the effects of all Oak Ridge plants, was less than 0.01 percent of the AEC radiation protection standard for natural uranium.

The average external gamma radiation measured in the town of Oak Ridge and at the perimeter of the Oak Ridge area was 0.012 mR/hr, which is approximately the same as that level measured during the period prior to Oak Ridge operations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	September 1966
January–June 1966	January 1967

SECTION V. TECHNICAL NOTES

Gross Beta Radioactivity in *FUCUS* Hybrids (Rockweed) From the Niantic Estuary, Connecticut, 1961-1964 [1]

Thomas W. Hatfield, Donald M. Skauen, and *Nelson Marshall* [2]

A study of gross beta radioactivity in various species of biota of the upper Niantic estuary was conducted from the fall of 1961 through the fall of 1962. A nuclear power plant is being constructed at Millstone Point, Waterford, Conn., which is in the Niantic Bay area. These studies represent a part of various studies on baseline radioactivity in the area.

Gross beta radioactivity was measured at approximately monthly intervals in a variety of marine organisms collected where they are relatively abundant along the axis of the Niantic estuary in Connecticut and from adjacent waters of Long Island Sound (figure 1). The collections included specimens of sea lettuce, rockweed, kelp, eelgrass (*Zostera*), two species of mussel, scallop, oyster, and both the hard-shell and soft-shell clams.

Except for two results of 1,042 and 572 pCi/g of ash for specimens of the hard-shell and soft-shell clams, respectively, collected November 21, 1961, none of the mollusks showed radioactivity in excess of 400 pCi/g ash. Except for the rockweed *Fucus,* none of the plants showed radioactivity in excess of 800 pCi/g ash. However, *Fucus*—particularly in samples taken near the headwaters of the Niantic estuary—showed high gross beta radioactivity levels during the winter of 1961–1962. The gross beta radioactivity level in *Fucus* also exceeded the

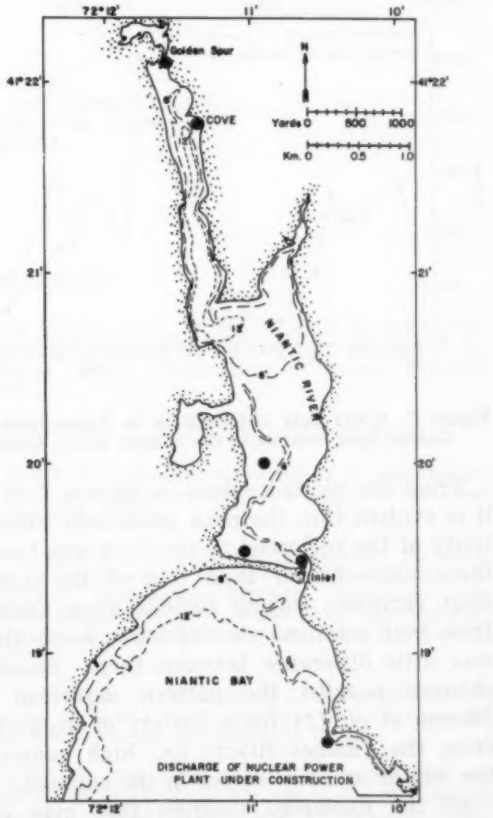

Figure 1. Niantic estuary, showing location of the Golden Spur, Cove, and other stations

[1] This study was supported in part by Research Grant RH-73 from the Department of Health, Education, and Welfare with the University of Connecticut, and in part by the Atomic Energy Commission under contract AT(30-1)-2678 with the University of Rhode Island.

[2] Professor Hatfield is chairman of Life Sciences, Mitchell College, New London, Conn.; Professor Skauen is professor of Pharmacy, University of Connecticut, Storrs, Conn.; and Professor Marshall is professor of Oceanography, University of Rhode Island, Kingston, R.I.

highs found in a wide variety of marine organisms taken from other locales in a broad program of monitoring along the southeastern New England shoreline (Skauen *et al.* (*1*), and Hatfield, unpublished data). Their monitoring included many samples of *Fucus* but none from the upper reaches of any other estuary.

To follow the gross beta radioactivity levels in *Fucus* in the upper Niantic estuary, sampling of rockweed was extended through January 1964 from the Golden Spur and Cove stations, where growths were abundant on rocks and small boulders in the intertidal zone. The results for the Golden Spur and Cove sampling areas are shown graphically in figures 2 and 3. The *Fucus* collected is considered to consist of an intertidal hybridizing mixture of *F. vesiculosis* and *F. spiralis* (*2*).

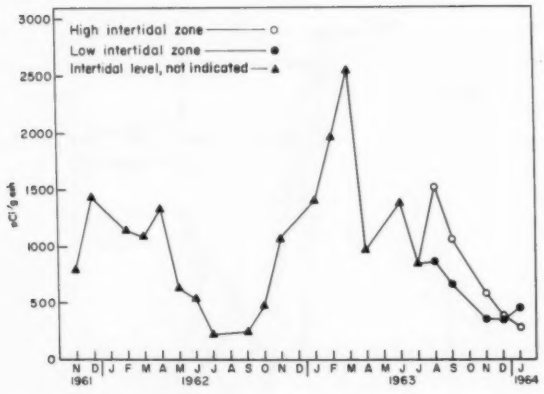

Figure 2. Gross beta radioactivity in *Fucus* from the Golden Spur location in the Niantic River, Conn.

From the plotted values in figures 2 and 3 it is evident that the peak gross-beta radioactivity of the rockweed in the Cove was two or three times higher than that of the Golden Spur samples. During periods when samples from both locations showed lower levels there was little difference between them. Seasonal changes parallel the pattern described by Skauen *et al.* (*1*) for a variety of organisms from the Thames River; *i.e.*, high values in the winter and low values in the summer.

Of the numerous nuclides that may contribute to this radioactivity, one—ruthenium—was ascertained by chemical separation by the

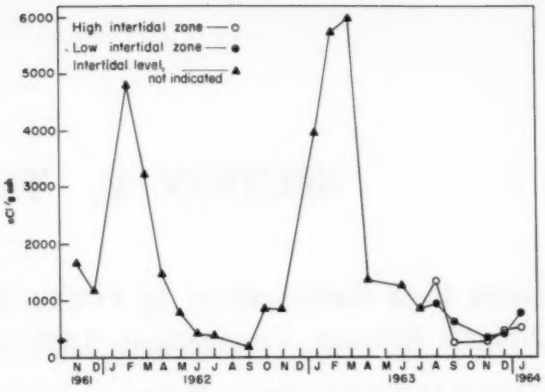

Figure 3. Gross beta radioactivity in *Fucus* from the Cove location in the Niantic River, Conn.

method described by Boni (*3*) for radionuclides in environmental samples. The analysis indicated that about 6 percent of the observed gross beta radioactivity can be attributed to ruthenium–103 and –106 and, though the percentage is small, it provides a clue to the sources and routes of contamination. In their review, Auerbach and Olson (*4*) indicate that very little is known about the movement of ruthenium through the environment, particularly the marine environment, although from the work of Tsuruga (*5*), it is known that some seaweeds may concentrate ruthenium. In the Niantic area it is difficult to conceive of a source of radioactive ruthenium other than from fallout. The high values in the upper Niantic estuary suggest that fallout is carried to the headwaters via watershed drainage. There is no apparent explanation for the higher levels of gross beta radioactivity in the Cove samples as compared with the Golden Spur samples, which are closer to the headwaters. Possibly factors such as undetermined hydrologic variation or differences in growth rates of the rockweed at the two locations play a role.

Relative to the environmental and uptake routes, the following seem pertinent:

1. The fluctuations in *Fucus* (figures 2 and 3) seem to follow by a few months changes in levels of gross beta radioactivity in the air at the Hartford-Providence stations (*6*) (figure 4). This relationship is not so obvious with respect to the total beta radioactivity in the precipitation at these two stations.

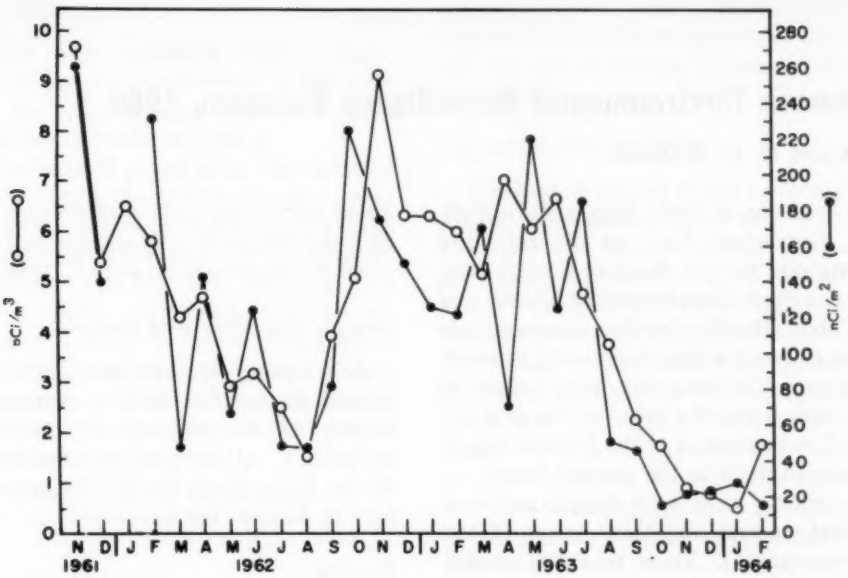

Figure 4. Gross beta radioactivity in air samples (left ordinate) and in precipitation (right ordinate). Averages for Hartford, Conn., and Providence, R.I., sampling stations

2. The highest results observed for *Fucus* occur during the time of greatest river discharge.

3. Gross beta radioactivity in *Fucus* samples shows seasonal variations. The few collections in which samples from high in the intertidal zone were compared with samples low in the intertidal zone suggest that there may be differences relating to elevation.

Noting the relationship of peak gross beta radioactivity in the air early in the winter, followed by peak gross beta radioactivity in *Fucus* at the time of maximum late winter river discharge, one may speculate that the gross beta radioactivity in the air accumulates in the watershed and runs off with late winter thaws and melting.

The foregoing preliminary findings suggest that extension of our studies on *Fucus* may provide a useful means of monitoring environmental releases of radioactivity.

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The Galveston Environmental Surveillance Program, 1966

B. Stewart and *M. C. Wukasch* [1]

With the selection of Todd Shipyards on Pelican Island, Galveston, Tex., as the refueling and servicing site for the Nuclear Ship Savannah, the Texas State Department of Health and the U.S. Public Health Service cooperatively initiated the Galveston Environmental Surveillance Program. The program was begun in June 1962, some 6 months prior to the first arrival of the N.S. Savannah at the Pelican Island site and has continued to the present time.

Previous reports have been distributed covering the first, second and third years of the sampling program (*1*). These reports included the sampling schedule, type of samples collected, location of sampling stations, and results of the analyses of samples collected during that time. This report is for the purpose of providing essentially the same information for that portion of 1966 when the N.S. Savannah was in Galveston Harbor. The N.S. Savannah arrived in Galveston Harbor June 1, 1966, and after a short period on public exhibition was docked at Todd Shipyards for repairs and modification until its departure on July 1, 1966.

Sample collection and analyses

A sampling schedule similar to the one conducted during the 1965 operation was maintained (*2*). Sample station locations are shown in figure 1. All samples collected were analyzed by the Texas State Health Department Laboratory in Austin, Tex.

Results

The analytical results of environmental samples collected in the Galveston vicinity are presented herein.

[1] Mr. Stewart is supervisor, Surveillance Activities Radiation Control Program and Mr. Wukasch is chief, Radiation Control Program, Division of Occupational Health and Radiation Control, Texas State Department of Health, Austin, Tex.

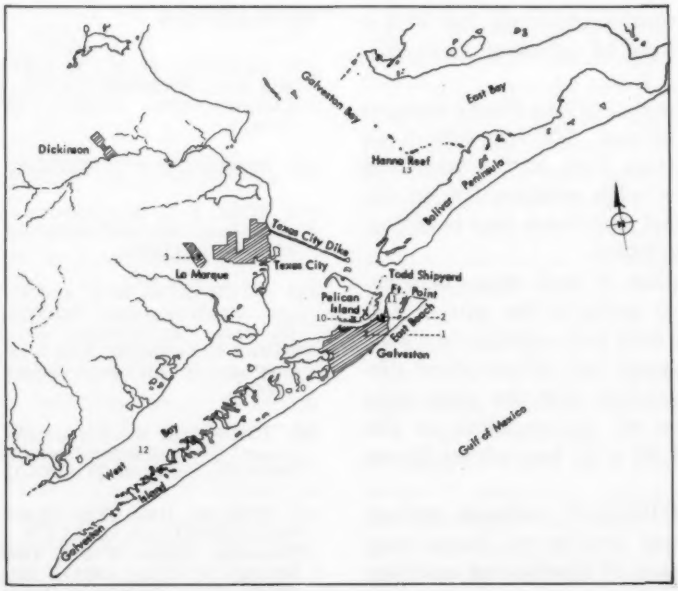

Figure 1. Galveston sampling locations

Air radioactivity

Air samples were collected with a high-volume sampler located on the roof of the Galveston City Hall. Gross beta radioactivity in these air samples is listed in table 1.

Wide fluctuations of gross beta radioactivity in air occurred during the first year's operations as reported in the previous report (*2*). Lesser variations were detected during the present sampling period. The increase noted during May and June 1966 is attributed to fallout resulting from the May 9, 1966 atmospheric nuclear test conducted by mainland China. Similar increases in radionuclide contamination were observed in milk samples collected during this time period.

Table 1. Radioactivity in air, Galveston City Hall Station No. 1

Date filter removed (1966)	Gross beta radioactivity (pCi/m³)
May 23	0.4
25	1.8
June 1	.6
3	.7
6	.4
8	NS
10	.9
13	.7
15	.3
20	.3
22	.3
24	.3
27	.3
29	.3
July 1	.3
6	.2
8	NS
11	.2

NS, no sample.

Milk radioactivity

The concentration of various radionuclides in the raw milk samples is listed in table 2. The detection of the short half-lived isotopes (iodine–131 and barium–140) as indicative of the presence of fresh fission products. Similar detections were noted throughout the entire United States during this time period as a result of the mainland Chinese test mentioned previously.

Table 2. Radionuclide concentrations in milk, Station No. 20

Date collected (1966)	Iodine-131 (pCi/liter)	Barium-140 (pCi/liter)	Cesium-137 (pCi/liter)	Strontium-90 (pCi/liter)
May 18	* <10	* <10	45	9
25	10	5	30	8
June 2	20	10	45	13
8	10	10	40	11
15	10	* <10	35	13
22	10	* <10	30	10
29	10	* <10	20	11
July 6	10	* <10	20	11
11	10	* <10	20	10

* Minimum detectable level is 10 pCi/liter (2 σ analytical error).

Sea water radioactivity

The high dissolved solids content of sea water makes the standard gross beta and gross alpha radioactivity determinations impractical from an analytical standpoint. Chemical fractionation of samples has therefore been necessary. The carbonate and basic sulfides fractions have been used in this study as indicators of sea water contamination. The radioactivity of the carbonate fraction is indicative of alkaline earths content. Strontium and radium are part of this chemical family. The radioactivity of the basic sulfides fraction is indicative of the transitional elements (*e.g.*, cobalt, zinc, iron, and nickel) and the rare earths (*e.g.*, cerium, yttrium, ruthenium, and zirconium). Interference because of sodium solids and potassium–40 radioactivity is eliminated by these two chemical fractionations.

Sea water samples were collected from two locations during this report period. Results of the analyses are given in tables 3 and 4. There was little change in the levels of radionuclide contamination found during the periods of the previous reports. The highest concentration in the carbonate fraction was 4 pCi/liter and in the basic sulfides fraction, 19 pCi/liter. These low levels can be attributed to natural background variations.

Radioactivity in silt

Silt samples were collected from the bottom of Galveston Channel at Station No. 11 (table 5), four times during the report period by means of a spring activated, hand operated silt dredge. The samples were collected prior to the arrival of the N. S. Savannah, during its visit and following its departure from the channel.

Summary

As the result of the 1966 operation of the Galveston Environmental Surveillance Program, it has been shown that no detectable ra-

Table 3. Radioactivity in sea water, Station No. 10

Date collected (1966)	Suspended solids		Dissolved solids				Gamma-ray scan (pCi/liter)
	Gross alpha radioactivity (pCi/liter)	Gross beta radioactivity (pCi/liter)	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)		
			C[a]	BS[b]	C[a]	BS[b]	
May 19	2	4	(c)	(c)	4	1	(d)
25	1	4	<1	(c)	(c)	2	(d)
June 1	NS	NS	NS	NS	NS	NS	(d)
8	1	1	<1	1	1	2	(d)
15	<1	1	<1	(c)	2	2	(d)
21	(c)	<1	(c)	9	1	3	(d)
29	<1	2	(c)	1	2	2	(d)
July 5	40	29	(c)	(c)	<1	3	(d)
11	<1	3	(c)	<1	2	1	(d)

[a] C, carbonate fraction.
[b] BS, basic sulfides fraction.
[c] Not significantly greater than background.
[d] No significant peaks other than potassium-40.
NS, no sample.

Table 4. Radioactivity in sea water, Station No. 11

Date collected (1966)	Suspended solids		Dissolved solids				Gamma-ray scan (pCi/liter)
	Gross alpha radioactivity (pCi/liter)	Gross beta radioactivity (pCi/liter)	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)		
			C[a]	BS[b]	C[a]	BS[b]	
May 19	<1	1	<1	(c)	1	10	(d)
25	2	3	(c)	19	(c)	1	(d)
June 1	1	1	1	1	2	2	(d)
8	(c)	1	(c)	(c)	1	2	(d)
15	(c)	1	(c)	13	1	8	(d)
21	(c)	1	(c)	(c)	1	1	(d)
29	24	23	(c)	11	1	7	(d)
July 5	(c)	2	(c)	1	1	1	(d)
11	(c)	1	(c)	(c)	2	(c)	(d)

[a] C, carbonate fraction.
[b] BS, basic sulfides fraction.
[c] Not significantly greater than background.
[d] No significant peaks other than potassium-40.
NS, no sample.

Table 5. Radioactivity in silt, Station No. 11

Date collected (1966)	Gross alpha radioactivity (pCi/kg)	Gross beta radioactivity (pCi/kg)	Gamma-ray scan (pCi/kg)
May 19	1.65×10^3	7.78×10^3	(a)
June 8	2.07×10^3	9.82×10^3	(a)
July 5	1.84×10^3	9.33×10^3	(a)
July 11	2.52×10^3	8.91×10^3	(a)

[a] No significant peaks other than potassium-40.

dioactive contamination occurred in the Galveston-Pelican Island area because of the operations of the N. S. Savannah. The low levels of radioactivity detected in the various environmental samples are attributed to naturally occurring radionuclides and mixed fission products resulting from the testing of nuclear weapons.

The results reported herein are almost entirely free of large fluctuations. The variations noted may all be attributed to the atmospheric test conducted on mainland China on May 9, 1966. With the exception of the milk samples, almost all the results are shown to be below or just above the detection limit. As was mentioned previously, the milk radioactivity trends followed closely the nationwide trend as reported by the U.S. Public Health Service.

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Radioactive Material Handling Problems in Oil and Gas Well Logging

J. H. Fontaine [1] and *D. H. Flora* [2]

Radioactive material has been used in oil and gas well logging since the late 1930's, but only during the last 5 to 10 years has expanded use of the technology become employed (*1*). The specific uses of radioactive material in well logging and its associated health physics problems have only recently achieved special attention by various State regulatory agencies and by the health physics profession as a whole (*2*). This note reviews some of the problems associated with the oil and gas well logging industry as observed in Texas. It is felt the experience in Texas is analogous to that of other States in which oil and gas drilling is actively being pursued.

The oil well drilling and servicing industries in Texas employ nearly 44,000 workers out of a total of 201,800 in the petroleum and petrochemical industry. While some oil-producing zones are located in densely populated areas within the State, the large majority of drilling has occurred in sparsely populated areas.

Radioisotopes are used in various ways to obtain information useful to the geologist in developing productive reservoirs of oil or natural gas, and in drilling and completing wells. As tracers, radionuclides permit the engineer to follow the movement of liquids or gases within a well bore or through the reservoir. By adding tracers to various materials emplaced in the well bore, one can determine the exact location of reservoirs. The use of sealed gamma-ray sources permits measuring the density of gaseous, liquid and solid materials within or surrounding the well bore. Sealed gamma-ray sources are also used as orienting devices in depth control and perforating. The beryllium (α, n) reaction produces neutrons which may be used in several ways. Bombarding a tritium target with deuterons produces an even more intense source of high energy neutrons. This technique has come to the forefront in the well logging industry by development and use of "down-hole" neutron generators.

Since March 1, 1963, when Texas became an agreement State, 63 radioactive material licenses have been issued, authorizing over 300 individuals to use radioisotopes in oil and gas well logging. This represents 7.0 percent of the total number of licenses issued. Careless handling methods and hazardous operations evolved from the widespread use of radium in the well logging industry and lack of previous government regulations concerning its use.

Probably the greatest radiation hazard in well logging is source handling. Direct source manipulation has been observed, despite the fact that proper handling tools have been devised which reduce radiation exposure to a minimum. These handling tools come in assorted sizes and shapes but their purpose is the same; namely, to reduce radiation exposure by the distance technique. Also, the use of plutonium-beryllium and americium-beryllium neutron sources rather than the older radium-beryllium source has become widespread throughout the industry to reduce high gamma-ray levels.

Proper storage of radioactive materials, whether at the company's factilities or on the logging truck, is another problem area in the well logging industry. Standard lead containers have been used incorrectly to store neutron sources, and paraffin shields have been used incorrectly to store large gamma-ray sources. Transporting containers with inadequate shielding have been frequently used with regard to radium-beryllium neutron sources. Very high exposure rates have been recorded

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in the proximity of logging trucks transporting radium-beryllium sources.

The use of radioactive material as tracers in well logging also presents some rather unique health physics problems. Since most radioisotopes used as tracers have a relatively short half-life, the main problem is one of personnel protection. Some of the prevalent isotopes used are iodine–131, iridium–192, scandium–46 and zirconium-niobium–95. Most companies have good safety procedures for the use of tracer material, but spills and contamination have been reported. The proper use of impermeable gloves, handling tongs, respirators and in some cases protective clothing can prevent personnel contamination. Contaminating underground potable water reservoirs is almost an impossibility as all oil and gas wells drilled in Texas are required to be cased through freshwater aquifiers. Most injected tracer material is designed to be permanently retained in the well bore or permeable formation of interest. However, material that does inadvertently come back to the surface may be diluted to acceptable limits in above ground drilling fluid reservoirs.

A comparison of the regulatory items of noncompliance found at oil and gas field licensees with industrial radiographers is presented in table 1. This comparison was chosen because of the close correlation between the work environment for the two industries. Both of these industrial operations are usually done in the "field," and the equipment would be subjected to much rougher treatment than would the majority of other users for radioactive materials. It is interesting to note that the percentage of times that they failed to maintain required records is identical in both industries. However, it has been found in Texas that the users of radioactive material associated with oil and gas fields are more delinquent in posting the required signs, labels, etc., than are the radiographers. The reverse situation occurs in operational procedures. This category covers not only the use of improper procedures, but also failure to perform required procedures as outlined in the Texas State Regulations for Control of Radiation (*3*). It should be pointed out here, that these regulations are generally identical and in all cases compatible with similar regulations enforced by the Atomic Energy Commission.

Table 1. Distribution of regulation violations for radioactive materials in oil and gas field licensees and industrial radiographers

Occupational type	Number of inspections [a]	Regulation violation		
		Posting requirements (percent)	Incorrect procedures (percent)	Recordkeeping (percent)
Oil and gas field licensees	94	48	42	10
Industrial radiographers	81	41	49	10

[a] The number of violations per inspection may have been more than one.

Table 2 shows the percentage of legally defined incidents by user category. Legally defined incidents may be summarized as: (1) incidents involving exposures to personnel, releases of radioactive material and property damage at levels which require immediate or 24-hour notification of the Texas Radiation Control Agency; (2) loss or theft of radioactive sources; (3) overexposures of individuals in excess of the regulations; and (4) levels of radiation or concentrations of radioactive materials in unrestricted areas in excess of the regulations. Sixty-seven percent of the 124 incidents summarized in this review occurred in industry and 37 percent of the industrial incidents occurred in the oil and gas well logging industry. Medical users accounted for 21 percent, while educational institutions showed the fewest number of incidents, with around 10 percent.

Table 2. Legally defined incidents reported

Occupational type	Number of incidents	Type of incident		
		Leaking sources or spills (percent)	Lost (percent)	Overexposure (percent)
All users [a]	124	35	35	30
Oil and gas field industry	46	39.1	56.5	4.4

[a] Includes medical, educational, and institutional users, as well as oil and gas well logging.

Improvement in well logging radiation safety is reliant on proper training. Courses in radiation fundamentals and radiological health practices are presented by the U.S. Public Health Service in cooperation with the Texas State Department of Health, as well as the various service companies which provide radioisotopes to the well loggers. In addition, training of

users during routine inspections has been performed by State inspectors, particularly in the use and associated hazards of neutrons. This training can be augmented by periodic company safety meetings which emphasize proper operational procedures.

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Reported Nuclear Detonations, July 1967

The U.S. Atomic Energy Commission announced one underground nuclear test conducted at its Nevada Test Site during July 1967. The test of July 27 was a low-intermediate yield test (20 to 20 kilotons TNT equivalent).

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

STRONTIUM–90 IN HUMAN BONES, 1964–1965. *R. M. Hallisey* and *M. A. WALL. Radiological Health Data and Reports, Vol. 8, August 1967, pp. 415.*

Results obtained from analysis of strontium–90 in human bone specimens from 303 individuals who died in 1964 and 293 individuals who died in 1965 have been studied. The bone specimens were collected at autopsies in selected metropolitan cities throughout the United States. A summary table of all the data for deaths occurring in 1964 and 1965 is presented. In most of the five age groups in 1965, average values are slightly lower than the 1964 values. Regional variations in the strontium–90 to calcium ratio are shown with the highest average for each year in the Delta region. The data were related to human bone concentrations that were derived from the Federal Radiation Council's Radiation Protection Guides and intake ranges, and it was shown that in both years the average bone concentrations corresponded to Range I of these intake guides.

KEY WORDS: age groups, Federal Radiation Council ranges, geographical distribution, human bone specimens, strontium–90/calcium ratios, strontium–90.

UPTAKE OF CESIUM–137 FROM CONTAMINATED SOIL BY SELECTED GRASS CROPS. *H. L. Cromroy, W. A. Goldsmith, C. R. Phillips,* and *W. P. Bonner. Radiological Health Data and Reports, Vol. 8, August 1967, pp. 421.*

The cesium–137 content of milk in the Tampa, Fla. area has been consistently above the national average in recent years. The possibility that grasses grown in this area receive their contamination indirectly through contaminated soil is being investigated. Among the grasses investigated in the uptake of cesium–137 appears to be greatest for pangola grass.

KEY WORDS: Bahia grass, cesium–137, contaminated soil, dairy feed, milk, Pangola grass, soil, uptake.

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